PB83-142133

Proceedings of the Conference on Combined Municipal/Industrial Wastewater Treatment Held at the University of Texas at Dallas on March 25-27, 1980

Texas Univ. at Dallas
Richardson

Prepared for

Robert S. Kerr Environmental Research Lab.
Ada, OK

Apr 81

U.S. Department of Commerce
National Technical Information Service
NTIS

PB83-142133

EPA-600/9-81-021
April 1981

PROCEEDINGS OF THE CONFERENCE ON COMBINED MUNICIPAL/INDUSTRIAL WASTEWATER TREATMENT

Presented by

United States Environmental Protection Agency

Center for Environmental Studies
University of Texas at Dallas

Project Officer

Thomas E. Short, Jr.
Source Management Branch
Robert S. Kerr Environmental Research Laboratory
Ada, Oklahoma 74820

Editor and General Chairman

Aharon Netzer
University of Texas at Dallas
Richardson, Texas 75080

ROBERT S. KERR ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
ADA, OKLAHOMA 74820

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/9-81-021	2. ORD Report	3. RECIPIENT'S ACCESSION NO. PB83 - 142 133
4. TITLE AND SUBTITLE Proceedings of the Conference on Combined Municipal/Industrial Wastewater Treatment		5. REPORT DATE April 1981 (preparation date)
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Aharon Netzer, Editor		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS University of Texas at Dallas Campbell at N. Floyd Road Richardson, TX 75080		10. PROGRAM ELEMENT NO. CBGB1C
		11. ~~CONTRACT/~~GRANT NO. R806799
12. SPONSORING AGENCY NAME AND ADDRESS Robert S. Kerr Environmental Research Laboratory U.S. Environmental Protection Agency P. O. Box 1198 Ada, Oklahoma		13. TYPE OF REPORT AND PERIOD COVERED Final (3/25-27/80)
		14. SPONSORING AGENCY CODE EPA 600/15

15. SUPPLEMENTARY NOTES

16. ABSTRACT

This conference presented the latest information on combined municipal/industrial wastewater treatment. The sessions were intended to bring together experts from the United States, Canada, Europe, and South Africa who have first-hand experience in the field of combined wastewater treatment systems.

The conference was for all engineers, scientists, officials, and operators who are involved in combined municipal/industrial wastewater treatment systems and seek to improve their knowledge and understanding of advanced treatment procedures for combined municipal/industrial wastewater treatment.

The curriculum of the Conference covered methods for treatment of combined municipal/industrial wastewaters; industrial pretreatment; case histories of industrial pretreatment effluents and combined municipal/industrial wastewater treatment; data on presence and fate of priority pollutants in existing municipal/industrial wastewater systems; research, design, and operation of combined municipal/industrial wastewater treatment; sludge handling, utilization and disposal; water reuse and recycling.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Industrial Wastes	Wastewater Management	68D
Waste Treatment	Municipal Wastes	91A
Wastewater		

18. DISTRIBUTION STATEMENT RELEASE TO PUBLIC	19. SECURITY CLASS *(This Report)* UNCLASSIFIED	21. NO. OF PAGES 556
	20. SECURITY CLASS *(This page)* UNCLASSIFIED	22. PRICE

NOTICE

Mention of trade names or commercial products does not consititute endorsement or recommendation for use.

FOREWORD

The Environmental Protection Agency was established to coordinate administration of the major Federal programs designed to protect the quality of our environment.

An important part of the Agency's effort involves the search for information about environmental problems, management techniques and new technologies through which optimum use of the nation's land and water resources can be assured and the threat pollution poses to the welfare of the American people can be minimized.

As one of these facilities, the Robert S. Kerr Environmental Research Laboratory is responsible for the management of programs to: (a) investigate the nature, transport, fate and management of pollutants in groundwater; (b) develop and demonstrate methods for treating wastewaters with soil and other natural systems; (c) develop and demonstrate pollution control technologies for irrigation return flows; (d) develop and demonstrate pollution control technologies for animal production wastes; (e) develop and demonstrate technologies to prevent, control or abate pollution from the petroleum refining and petrochemical industries, and (f) develop and demonstrate technologies to manage pollution resulting from combinations of industrial wastewaters or industrial/municipal wastewaters.

The conference on Combined Municipal/Industrial Wastewater Treatment was held at The University of Texas at Dallas on March 25-27, 1980. This conference presented the latest information on combined municipal/industrial wastewater treatment. The sessions brought together experts from the United States, Canada, Europe, and South Africa with their first-hand experience in the field of combined municipal-industrial wastewater treatment systems.

The curriculum of the conference included methods for treatment of combined municipal/industrial wastewaters; industrial pretreatment; case histories of industrial pretreatment effluents and combined municipal/industrial wastewater treatment; data on presence and fate of priority pollutants in existing municipal/industrial wastewater systems; research, design, and operation of combined municipal/industrial wastewater treatment; sludge handling, utilization and disposal; water reuse and recycling.

Clinton W. Hall
Clinton W. Hall
Director
Robert S. Kerr Environmental Research Laboratory

TYPING GUIDE SHEET
EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE

CONTENTS

Foreword iii

Keynote Address, S. R. Reznek, "An Overview of EPA Joint (Combined) Industrial Waste Research Program". 1

SESSION I. 7

J. G. Moore, Jr., "Innovation in Wastewater Treatment" 7
R. M. Southworth, "Industrial Categorical Pretreatment Standards" 16
S. Sacks, "Minimizing Costs by Good Financial Management". . . . 24

SESSION II 31

A. W. Busch, "Compatibility Assessment of Municipal/Industrial Wastewaters for Combined Biological Treatment". 31
E. L. Stover, "Biological Inhibition Screening of Industrial Wastewaters". 45
D. F. Kincannon et al, "Treatment of Municipal Wastewaters Containing Biologically Hazardous Industrial Compounds by Conventional Activated Sludge and Extended Aeration". . . . 60
J. van Leeuwen et al, "The Treatment of Combined Industrial and Domestic Wastewater for Reuse in South Africa". 79
P. B. DeJohn et al, "Use of Granular Activated Carbon to Treat Municipal Wastewater Receiving Industrial Flow" 93
J. L. Taylor, "Full Scale Experience with Activated Carbon Treatment of Joint Municipal-Industrial Wastewater" 113

SESSION III. 122

C. A. Pitkat, "Textile Waste Treatment at a Municipal PACT* Facility" 122
R. G. Rice, "Review of the Use of Ozone for Improving Combined Municipal/Industrial Wastewater Treatment". 141
A. J. Acher, "The Use of Solar Energy for Combined Municipal-Industrial Wastewater Treatment". 167
C. E. Pound et al, "Land Treatment of Combined Municipal/Industrial Wastewaters" 180
L. E. Sommers and D. W. Nelson, "The Utilization of Sewage Sludges on Cropland". 188
Amatzya Eyal, "Utilization of Activated Sludge from Combined Municipal/Industrial Wastewater Treatment for Animal and Poultry Feed" 209

Preceding page blank

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD. BEGIN SECTIONS HERE

SESSION IV 214

J. M. Craddock, "Water Pollution: Industry and Government Working Together - A Case Study of Muncie, Indiana's Industrial Pretreatment Program" 214

E. G. Wright et al, "The City of Chattanooga Industrial-Municipal Pretreatment Program". 230

E. C. Monnig et al, "Investigations on the Suitability of Various Pesticide Manufacturing Wastewater for Discharge to Municipal Waste Treatment Facilities" 259

L. S. Directo, et al, "Los Angeles County Experience in the Control and Treatment of Industrial Wastewater Discharges" . 272

A. Netzer et al, "Combined Municipal-Industrial Wastewater Treatment in Garland, Texas" 300

SESSION V. 313

G. M. Doughty, "The Treatment of Cotton Waste in the Mersey Basin" 313

A. W. Wilson, "Case Study of a Potato Chip Producer Discharging to a Small Municipal Treatment System" 329

J. D. Lowry, "Joint Treatment Design and Operation Problems with a Fine Paper Manufacturing Wastewater". 353

K. C. Bradley, "Uniroyal Chemical's Experience with Combined Municipal-Industrial Wastewater Treatment at Elmira, Ontario" 381

D. W. Pickard, "Industrial Compatibility with the POTW in Tampa, Florida, through City/Industry Cooperation" 388

R. Seraydarian et al, "Sources of Toxic Pollutants Found in Influents to POTW's" 395

H. D. Feiler et al, "Treatment and Removal of Priority Industrial Pollutants at Publicly Owned Treatment Works" 414

A. C. Petrasek, Jr., "Behavior of Selected Toxic Substances in Wastewater Collection and Treatment Systems". 453

F. B. DeWalle et al, "Effect of Combined Treatment on Priority Pollutants in POTW's" 478

R. A. Minear et al, "Heavy Metals in Municipal Wastewater Treatment Plant Influents: An Analysis of the Data Available from Treatment Plants" 488

K. J. Yost et al, "Sources and Flow of Heavy Metals and Cyanide in the Kokomo Municipal Treatment System". 521

H. M. Jeffus, "Problems with Metals in the Residue from Combined Municipal/Industrial Waste Treatment" 544

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

PB83-142141

BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD, BEGIN SECTIONS HERE
6-1/2"
9-1/8"

KEYNOTE ADDRESS

AN OVERVIEW OF EPA JOINT (COMBINED) INDUSTRIAL WASTE RESEARCH PROGRAM

S. R. Reznek
Deputy Assistant Administrator for Environmental Engineering & Technology
U.S. Environmental Protection Agency
Washington, D.C. 20460

INTRODUCTION

The subject of combined treatment is complex and, frankly, confusing. I am not sure that I understand the Federal policies and programs exactly, and I was part of their development. The issues and questions epitomize all the issues and questions that make pollution control and environmental protection an

- interesting
- frustrating
- and generally cantankerous issue.

The source of the problem is the same as it is in everyone of our day-to-day affairs. Not only do we not know all we need to know to make perfect decisions, we have not even found out everything we could conceivably find out before we make them.

How many of you read the catalog of universities you applied to before selecting one? How many of us interview the university teachers? How much study do we do before making a personal or corporate investment?

In the environment area, the lack of knowledge creates two dilemmas. The first is related to time, i.e., more study or action now. Congress has spoken on that point several times and usually the legislation demands action. Second, decisions made without total knowledge will not be efficient. That means they will be less cost-effective than they could be--could be in the theoretical sense. Could be if we waited and studied. Could be if we did not decide until later. Russell Train used to say:

(1) We are neither so poor that we cannot afford the costs of pollution controls, nor are

(2) We so rich that we can afford not to pay the costs of preserving our environment.

BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
BEGIN LAST LINE OF TEXT
3/8"
PAGE NUMBER

EPA-287 (Cin.)
(4-76)

These words remain true. However, we now have a 20% inflation rate. The single indispensible material resource used in all manufacturing--energy--is multiplying in price. I guess we are coming to realize that Train's remarks have to be expanded to include:

(3) We are no longer so endowed with resources that we can afford to waste them.

Pollution controls must be cost-effective and resources must not be used in inefficient measures. Theoretically, I could design an efficient area-wide wastewater management program. Let's look at the nature of the problem. First, the system consists of many small discharges. All of them can discharge to a central system, and some have the option of direct discharge. All can control their water use and some can pretreat their wastewater before discharging to the central facility.

The problem of defining the most economical configuration is extremely complex. Environmental performance is determined by the net discharge of pollutants and costs by the nature of technologies selected.

Now look at the real problem. Discharge does not simply mean biological oxygen demand (BOD) and suspended solids. It now means four sanitary and 165 toxic pollution parameters. We don't know how to add them together precisely. Further, the interest, i.e., a toxic pollutant, will affect the BOD removal efficiency. Most unfounding of all, it is not the time-averaged toxic pollutant load that affects BOD removal performance, it is the time variations and short-term high concentration conditions that actually affect performance.

On the cost side, the real situation is more complex than simply total cost. Costs are paid by municipalities for the collection systems and for treatment plants. Costs are also paid by the industries for pretreatment. Private and public bodies will obviously have different financing costs. The Federal Government underwrites some of the municipal costs and, as usual, we have rules--rules about recovering the Federal share for industrial treatment and for having the municipalities set user fees to collect that share.

The real problem of protecting the environment is even more complex. Wastewater treatment will create solid wastes. These sludges will have their own implications for regional environmental quality and municipal and private pollution control expenditures. So real problems are very complex, indeed. Regional systems include numerous small discharges, a central treatment capability, the need to control the environmental impacts of over one hundred pollutants, and the costs and environmental consequences of disposing of municipal sludge and industrial treatment residuals.

Unfortunately, we do not know enough to design these systems in great detail. But we do know enough to design good systems and to avoid gross inefficiencies. EPA's research program tries to generate the information necessary for better decision.

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE
6-1/2"
9-3/8"
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

EPA RESEARCH PROGRAMS

EPA's industrial/municipal research is in four areas:

Combined treatment
Industrial pretreatment
Residuals management
Areawide industrial treatment

Combined Treatment

Joint treatment research involves the study of the combined treatment of industrial and municipal wastewaters in the publicly owned treatment works. Here, the concern is the effect the industrial contribution has on the municipal treatment system. Does the toxicity of these wastes reduce treatment efficiency? What happens to various industrial components in the municipal treatment system? Can these industrial components be biologically degraded? Are they air-stripped into the atmosphere? Do they attach to the sludge solids or do they simply move through the system and end up in the effluent? The ultimate objective of studies in combined treatment is to develop a sound understanding of the capacities of municipal treatment systems to reduce conventional and toxic industrial pollutants.

Pretreatment

The pretreatment effort, as the name implies, involves the study of the treatment of industrial wastes prior to their discharge into a municipal waste treatment plant. A knowledge of pretreatment performance, coupled with a knowledge of capabilities of municipal systems to handle industrial waste components, can lead to the development of cost-effective pretreatment guidelines.

Residuals Management

The treatment of wastewaters inherently generates waste solids or treatment sludges. Some industrial pollutants, such as heavy metals, tend to concentrate in wastewater sludges. The effect of industrial components on the characteristics of municipal sludges may be very critical in the consideration in determining disposal options and costs. The industrial components may make the sludges ecologically unsuitable for land application. Heavy metals in the sludge may well be controlled to acceptable levels by pretreatment of industrial wastewater.

There are other aspects of residuals production that must be considered. Industrial pretreatment will also create a residual problem. Instead of having a single source located at one municipal treatment plant, pretreatment may create many small sources of residuals. These wastes have to be properly managed. Areawide planning efforts should consider an optimum resource recovery scheme that will recycle these residuals. The institutional factors of collection, transportation, and final disposal of pretreatment residuals, along with industrial waste treatment residuals, are among the problems studied in our "Residual Management" area.

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

Areawide Industrial Treatment

While not widely practiced in this country, centralized industrial wastewater treatment is often an economically attractive possibility. A prime example of this concept is the Gulf Coast Waste Disposal Authority's plants near Houston, Texas. In highly industrialized areas it may be economically feasible to construct industrial sewers which transport industrial wastewaters from several sources to a central treatment plant dedicated only to industrial waste treatment.

Research Projects

For several years now, EPA's program has been involved in a number of projects to help solve some of the problems of combined industrial/municipal treatment. I would like to discuss some of EPA's active projects.

Allegheny Grants

In cooperative projects with Allegheny County, EPA will evaluate the residual management problems and resource recovery potentials that exist in the highly industrialized area near Pittsburgh, Pennsylvania. Waste Water Treatment Sludges and other process residues air cleaning, and industrial manufacturing are produced each day in Allegheny County. As residue quantities increase and disposal options become more constrained because of new laws and regulations, the cost will increase.

Steel mills and other primary metal industries, plating and coating operations, foundries, nonferrous metals, and all add to the problems and costs of waste.

The objectives of this study are to:

1. Determine distribution, volume, and characteristics of industrial wastewaters and sludges in Allegheny County.
2. Determine best practical treatment for industrial sludge volume and characteristics for area treatment plants.
3. Investigate possible future waste types and volumes.
4. Develop alternatives for collecting, disposing, and recycling the area wastes.
5. Develop a complete county residual treatment management system.

Municipal and Flue Gas Desulfurization Sludges

The beneficial use of a waste material offers one of the best solutions to sludge disposal problems. This was the goal of a cooperative project with the Dravo Lime Company. The purpose of the project was to combine flue gas desulfurization sludges with municipal sewage sludge to produce synthetic

BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
BEGIN LAST LINE OF TEXT
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

fertile soils. These soils could be used to reclaim land and, at the same time, solve the disposal problems of these waste sludges.

During the project, over 240 different mixtures of municipal and flue gas desulfurization sludges were prepared. Each mixture was tested for permeability, density, leachate composition, germination potential, and chemical composition, including heavy metals analysis. The most promising artificial soils were tested to evaluate their ability to support plant life. This testing included monitoring of plant growth and heavy metals uptake by the plants. The results of the study indicate that this type of synthetic soil does have a useful application.

The Susceptibility of Metals to Treatment in Combined Systems

In a research grant project with the Illinois Institute of Technology, we are evaluating the mechanism of metals removal in joint industrial/municipal systems. In past efforts to develop pretreatment guidelines, surveys of heavy metals removal in combined systems have not yielded consistent results. Removal efficiencies ranging from zero to near 100 percent have been reported for nearly all the metals studied. The objective of the project is to clarify the relationship between the chemistry of wastewater and the extent of metals removal and to develop a method of predicting metals removal.

The results of this study indicate that metals removal can be explained by considering the chelating properties of the organic materials in the effluent and the ability of the biomass and the suspended solids to adsorb metal species. Experiments have shown that operational parameters such as sludge age can influence the chelating chemistry of the wastewaters and sludges. The important parameters are, first, the types and quantities of metals that are present and the presence of industrial chelating material, such as cyanide. The most important factors affecting the chelating capacity of the organic material in the effluent seem to be sludge age and the presence of digester supernatant.

Muncie Pretreatment Case Study

Pretreatment standards will require most municipalities to affect programs which are successful in reducing industrial discharges through publicly owned treatment works. Muncie, Indiana, has had a very successful pretreatment program in effect since 1972. Through a research grant, Muncie has undertaken to produce a case study document as guidance to other communities faced with similar problems. Elements of this case study will include: a detailed description of the Muncie area, the motivating forces behind the development of their program, the effects of legislation, their sewer ordinances, industrial monitoring, their surcharge systems and cost recovery programs, enforcement, their sludge application program, water quality improvement in receiving streams, the effects of pretreatment program on the wastewater plant, estimates of the costs incurred by industry, and the industries' choices to participate or build their own treatment systems.

In addition to the case study, Muncie will carry out a sampling study of its system to determine the source of priority pollutants and to evaluate

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA: OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

the fate of these materials during treatment. Also, they will evaluate the residual management practives in their area.

1. They will identify the sources, transportation, and methods of disposal for all industrial residuals generated within this area.

2. Evaluate the effective means of maximizing resource recovery and minimizing environmental impact and operating costs of treatment.

Biological Simulation Monitor

In a grant with Vanderbilt University, we have undertaken to develop a monitor which can evaluate changes in the influent in order to determine if these changes will affect plant operation. A shock load from an industrial contributor can destroy plant efficiency. A biological simulation monitor provides a means of continuously monitoring the influent to a treatment plant for variations in chemical or physical composition.

These studies involved a specifically designed continuous respirometer. The biological simulation monitor system is an early warning system using a laboratory scale activated sludge unit. The feed to the system is the treatment plant's influent. Laboratory studies employing controlled feed to the microorganisms have shown the biological simulation monitor system can give a rapid response.

On-site testing at two treatment plants have corroborated the laboratory results. During field testing, the biological simulation monitor was able to indicate changes in the influent three hours before the flow reached the aeration basins.

CONCLUSION

The projects that have just been discussed represent only a few of the many that have been and are being undertaken by our industrial/municipal research program. These were presented only to indicate some of the types of studies that we are undertaking in an effort to solve the many problems that exist in the industrial/municipal waste treatment area. I am sure that in the future our Agency's efforts will continue to expand in this vital area. The problems of an expanding list of "priority pollutants," residual disposal, and the reuse and recycle of wastes will present future challenges.

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

PB83-142156

INNOVATION IN WASTEWATER TREATMENT

J. G. Moore, Jr.
Graduate Program in Environmental Sciences
The University of Texas at Dallas
Richardson, Texas 75080

TEXT

Innovative technology is something new, or changes in anything already established, new things or methods. Is there really anything new or have we seen much new in the development of treatment of wastewater? Have we seen much new in the combined treatment of municipal and industrial wastewater? I think not. I have been involved in water pollution control since the mid 1960's. There have been enormous sums spent in research and development at all levels of government, and I'll have to say that I am pessimistic that we will develop much dramatically new in terms of wastewater treatment. Now that should give you a good beginning, since there are those who will talk about innovation and wastewater treatment.

To some degree, I think the regulatory structure under which we in the United States currently work militates against the development of innovative or dramatically new technologies. I think combined industrial and municipal wastewater treatment offers an example of the complications that arise in attempting to advance the way we do things. Prior to the passage of Public Law 92-500 in 1972 there was much encouragement for combined municipal industrial treatment; there was a deliberate national policy that joint treatment would be encouraged. There were imagined, or claimed, or stated advantages of combined municipal industrial wastewater treatment, one being an economy of scale so that the cost both to the municipal resident and to the industrial discharger would be less than if each discharged separately. There was a concept of the dispersion effect of combined wastewater treatment where industrial waste distributed through municipal systems could be adequately treated or dispersed, so to speak, diluted perhaps, in the treatment process. There was, in terms of local financing perhaps--where there were industrial user charges--a concept that the municipality would have to finance that share of the treatment facilities with the charges collected from industries. Public Law 92-500 and subsequent statutes at the Federal level, of course, have further restricted the application of combined industrial-municipal wastewater treatment from major facilities. First the requirement for pre-treatment and secondly, the industrial cost recovery and user charge systems have tended to reduce the advantages of combined municipal-industrial wastewater treatment.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

So you will have no misunderstanding about where I stand, the concept of industrial cost recovery was a ridiculous idea to begin with and has become more ridiculous as the years have passed. There was an equity theory, largely advocated by Leon Billings on Senator Muskie's staff on the Subcommittee on Environment of what was originally the Senate Public Works Committee, that somehow or other the industrial cost recovery idea was an equitable approach to the differential that might exist between the cost for an industry discharging directly to a stream and the industry discharging through a municipal system. Whatever imagined advantage may have been enjoyed by the industrial discharger into a municipal system has largely been erased--in fact, it may now be more expensive to go through a municipal system than it would to discharge directly--has largely been erased by the industrial cost recovery concept and pre-treatment regulations being issued by the Environmental Protection Agency. The industrial cost recovery concept has not yet been fully implemented yet, since Congress itself has postponed the effective date repeatedly. Legislation is now pending in the House that would eliminate the industrial cost recovery concept from Public Law 92-500 and the Clean Water Act of 1977. The major disadvantage, as far as I'm concerned, to the industrial cost recovery idea is that whatever money may eventually reach the Federal Treasury for that share of the cost of municipal wastewater treatment planned to accomodate industrial waste will be considerably offset by the cost of the multiple audits and bookkeeping that has to occur at the local, state, and federal levels to account for that relatively small percentage of the total cost of most municipal systems. In other words, if there were a cost accounting of the industrial cost recovery system, the chances are we would discover that, in total, the Federal Government is losing rather than gaining money from the industrial cost recovery concept. A report, commissioned by the Environmental Protection Agency and done at their expense, recommended that the industrial cost recovery system be eliminated, but the Environmental Protection Agency (EPA) has not yet embodied that suggestion in legislation. EPA has generally gone to the Congress with the position that industrial cost recoverv should be continued. One of the effects, I think one of the inevitable effects, of the combined industrial cost recovery and user charges for maintenance and operation expenditures will be to reduce industrial water use. I don't think there is any doubt that, over time, there will be a gradual reduction in water use by industries that discharge into municipal systems. This may have some interesting kind of side effects. For example, in Detroit, where the first major rate increase for maintenance and operation expenditures has just been imposed, my guess is that industrial water use will decline somewhere between 15% and 25% in the next two years. This means that the income on the water supply side of the Department's operations may well decline, and it certainly means that in the long run, on the wastewater treatment side the income may decline. Thus, the cost will probably be redistributed among the other users of the system, since the capitalization of the system has already been established.

Another impact on combined municipal-industrial treatment is the pre-treatment requirement. Despite the fact that pre-treatment regulations were supposed to have been issued six or eight years ago, not all the pre-treatment regulations are yet out--that is, the requirements for pre-treatment by industrial category--and the conclusion that pre-treatment had to be equal to

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

the "best available technology economically achievable" under the 1972 amendments (and a similar approach to pre-treatment requirements today) almost eliminates any economic advantage to the industrial dischargers through municipal systems. For example, if the pre-treatment regulations are, in effect, the same as what would have been required for the 1983 Phase II effluent limitations, and an industry must in addition pay the volume charges and the strength charges for whatever remaining wastewater goes into the municipal system, the chances are that the cost will be greater for the industry to discharge into the municipal system than it would be if it discharged directly into the receiving water. Admittedly, a lot of industries in a lot of places are captives of the system--that is to say, there is no available place into which they can discharge. In Detroit, where the major concentration of industry is related to the production of automobiles, obviously a direct discharge within the city would be extremely difficult, particularly for the wastes that are generated in that industry. If a discharge by municipal systems is into "water quality limited waters," as opposed to "effluent limited waters," as classified by the Environmental Protection Agency, the cost could be even greater. Simply because the publicly owned treatment works may have to meet, for those perameters that are affected by the waste, strict requirements than might otherwise be imposed if they were located in a less populated area of people and industry, pre-treatment costs may be considerably higher.

Leon Billings has another concept that has permeated the Federal Water Commission Control Act and that is that pollutants are really just resources out of place. That is, if we could just find a way to get them back where they belong, we would not have any waste. That's sort of believing if you keep on burning a fire in your fireplace, you will eventually burn up all the ashes; and those of you who have fireplaces know that is an impossibility. There is always a residual, and the chances are that there will always be a residual, for which no one has any use at all. It may be merely a substance that accumulates in a very small quantity somewhere, but nevertheless, there is some ultimate residual. Not everything is capable of being completely recycled. Nevertheless, the combination of industrial cost recovery requirements and pre-treatment requirements undoubtedly means that industries which pay attention to their costs will inevitably attempt to find ways to recycle those substances that are in their waste streams. By the way, that may in the long run be the most cost effective way for industries to dispose of the pollutants that would otherwise be in their discharges. It is important for industries to recognize that cost effectiveness is a relative question, that the disposal of wastes should be constantly analyzed. The mere fact that it was determined three years ago, or five years ago, that a particular scheme for the disposal of the residuals was not cost effective does not mean that the same circumstances hold true today. With both pre-treatment requirements and effluent limitations for direct discharges becoming more and more strict as we move into the future, the chances are the costs will be higher and higher. As the costs of the discharge of substances becomes higher, the possibility for gaining by recycling may be inevitably more economic, in the cost effective sense, than it might be today, so the matter must be reviewed constantly by an industrial discharger.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

Frankly, in my view, the most complicated questions facing all of us involved in water pollution control--and to some degree in air pollution control too--is the disposal of that final residual that will always remain. The current schemes for control have largely ignored the rising mountain of sludges and residuals all over the U.S. The restrictions upon the disposal of solid wastes are an unplowed field in terms of water or air pollution control, which is to say, whatever restrictions we have felt are strict, under the air and water pollution control acts, are nothing like what we will see in the control of sludges. One obvious consequence is that as the levels of required treatment increases, the volume of sludges will also multiply. For the municipal wastewater treatment plant, the volume of sludges is enormous.

Today in Detroit, we are averaging a flow in the range of 600 million gallons a day through a wastewater treatment plant that is not yet performing to secondary treatment levels--remember, we generate 35 hundred tons of wet sludge daily. Existing incinerators are unable to burn that thirty-five hundred tons, and we are currently hauling an average of 15 hundred wet tons a day of sludge. At present, there is only one disposal site to which Detroit sludge can be hauled, and before it can be hauled there, it must be neutralized with lime and the solid content must be increased to 40% by the addition of the ash--from the incineration process--which means that we must conduct a mixing process between the final dewatering step and the disposal of the sludge. The City has spent between 8 and 10 million dollars during the last twelve months attempting to locate sludge disposal sites in the state of Michigan; we have had sludge hauled illegally into Pennsylvania and illegally into Ohio, and disposed of illegally in the state of Michigan.

If you think the problem is complicated today, the estimate is that Detroit must plan for the ultimate disposal of somewhere in the range of 8 to 10 thousand tons of sluge per day at 22% to 25% solids for the next five years. The annual budget for sludge disposal over and above the cost of incineration for the Detroit Water and Seweage Department is 13 million dollars. That does not cover the cost of evergy for incineration nor does it consider the capital investment or the debt of service on the capital investment, that is being expended to achieve more effective incineration and more effective air pollution control. The City is faced with the prospect of the expenditure of something in that range each 12 months indefinitely into the future for the disposal of sludge.

What can be done? There is now pending in the Michigan Department of Natural Resources a set of regulations, the net effect of each would be to classify Detroit municipal sludge as a hazardous waste, under a state statute. Some of you may know that the Environmental Protection Agency had an internal battle of some magnitude between those responsible for wastewater treatment and those responsible for solid waste disposal as to the classification of municipal sludge as hazardous at the Federal level. After an enormous expenditure of energy, the wastewater treatment side won, and municipal sludge was not declared to be hazardous. The Michigan Department of Natural Resources says that, under the state statute under which the regulations are being developed, they have no alternative but to promulgate the regulations as presently drafted. There are no approved hazardous waste disposal sites in the state of Michigan. Now if you want to contemplate an

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

enormous problem think of forty thousand tons of wet hazardous sludge. My recommended solution to the Mayor of Detroit is, if the regulations do become effective, that Detroit haul its sludge to the Capitol grounds in Lansing. We are fortunate--they are fortunate in Michigan--Detroit may be fortunate--that before the regulations can go into effect, they have to be endorsed by the joint House-Senate Rules Committee. The legislature is predominantly Democrats; the Governor is Republican; the Detroit Mayor is Vice-chairman of the National Democratic Executive Committee, but he has an unusual working relationship since the Mayor was able to get the Republican, but not the Democratic, Convention in Detroit. We have a Republican Judge who was Eisenhower's campaign manager in Michigan some years ago, who was appointed by President Nixon to the Federal bench; thus we have a Republican Judge, a Democratic Mayor, and a Republican Governor working to change the regulations in the Rules Committee of the State Legislature, which is Democratic. We have told the Michigan Department of Natural Resources that that is the way we will go. Don't ever forget, everything has to be somewhere. If we can't burn it--and we might not be able to burn it if it is declared a hazardous waste--if we can't burn it, and we can't bury it, but we have to remove it from the water, we have to put it somewhere. By the way, there is no place on the Detroit Wastewater Treatment Plant site to put dewatered sludge. A year ago at this time there were between 10 and 15 tons of frozen sludge on that Plant site. They didn't have room for it then. There were piles, generally 4 to 5 foot high, alongside every road on the treatment plant site, between all the buildings, and piled up on the back side of the treatment plant site at a place where they intend to build primary clarifiers--an enormous mountain of frozen sludge, and then came the spring's thaw.

One possible solution for sludge disposal sites is State responsibility for their location and permitting. When I say State responsibility, I mean that a State agency should take the lead in locating, establishing, and permitting waste disposal sites. Detroit will have very little success finding disposal sites for Detroit sludge. Nobody outside Detroit wants that sludge from those people in Detroit deposited in their neighborhood. Even the suburbs that send the major part of that sludge to the Detroit wastewater treatment plant don't want it back in the suburbs. Of course, facetiously, one could always say the solution may be to just hold it.

If you think the problem is complicated now, the Michigan Department of Natural Resources is also planning to require that Detroit, or was planning (I hope we have avoided it.) to require the Detroit sludge to be tested for every pollutant on EPA's priority pollutant list, which now numbers some 150, and inevitably will increase as time passes. There are some listed pollutants for which there is not even yet a testing methodology.

Well, sludge is a problem; and sludge is a problem for combined systems. The Detroit system has roughly 25% of the wastewater from industries, and the industries from which it takes the waste are often the most complicated ones in terms of treatment. As you might expect, Detroit has a large number of electroplating plants of all kinds and their wastewater comes into the Detroit system. There is, as yet, no pre-treatment program effective in Detroit, but one is being developed according to the schedule presently provided in Federal regulations. Water reuse may, in time, cause us to pay more

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD. BEGIN SECTIONS HERE

attention to some of the pollutants that we now leave in the water. That may not necessarily help much, because if we manage to remove them from the water, we merely have them somewhere else. In other words, the emphasis across the country on water reuse may provide some benefit in terms of the treatment process but it will not simplify the disposal of pollutants, where we are more likely to get water reuse in those industries that decide that is the way to reduce the cost of treating their industrial waste discharge.

Where is the opportunity for innovation in all of this process? The chances are that the opportunity for innovation will lie in pre-treatment of industrial wastewater and not in the treatment of combined municipal-industrial wastewater. In my view, the chances are that the greatest opportunity for innovation will lie not in the wastewater treatment process but in the very production process itself. The most enlightened industries in the country will be those which decide that they will, in so far as possible, approach that ultimate goal that has been so widely acclaimed, no discharge of any pollutants. I suspect that the industries that survive and prosper in the longest run will be those which change the production process itself, in order to reduce both the volume of wastewater discharge and the volume of pollutants in that wastewater. If that means recycling, that will be the focus of the activity. If that means reuse, then that will be the focus of the activity. But there are imaginative minds conscious of the cost that know in the long run it is the production process itself which must be changed in order to reduce the total cost.

I am going to provide some suggestions for the various parties that are represented here. I always like to do this because I can tell people what they ought to do without having any responsibility for the outcome. My first one is for the EPA. The EPA should decide, at the national level, whether it favors or opposes combined municipal-industrial wastewater treatment or whether there is no real policy and it's not going to address the question one way or another. My view is that the Agency has, in effect, through its application of regulations under the existing statutes, actually discouraged combined municipal-industrial wastewater treatment. I think the EPA should tell the Congress that the industrial cost recovery provisions of the existing statute are impossible to administer and do not return a significant sum of money to the U.S. Treasury when measured against the total administrative, accounting and auditing costs and that it should be eliminated from the statute. Whatever presumed advantage there may be for the industrial discharger into municipal systems is eliminated by the cost of the recovery of the Federal share, the pre-treatment requirements and the user charges for operations and maintenance imposed on industrial users. I doubt seriously, at this point in time that it has made a significant difference in cost to the industry, or would make a significant difference in cost to an industry, whether it is located within or without a municipal system. For the states, I have a question. Are you prepared, in the long term, for redistribution of the major industries in your state so that they become direct dischargers, rather than being located within the jurisdictions of publicly owned treatment works? I think that is the inevitable result of the current policy. Admittedly, a lot of industries are captives of the publicly owned treatment works system. But, they won't be forever, because industry does not remain

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

static or constant. It will have opportunities to disperse; as industrial facilities become old and production processes become out of date, there are opportunities to close those facilities that are old and out of date. I suspect that, in the future, one of the considerations for the location of industrial facilities will be an attempt to locate in areas that are not water quality limited and outside the jurisdiction of publicly owned treatment works so that they do not have to go through one additional level of regulatory administration to meet water quality or wastewater treatment requirements.

For industries, I believe you should constantly review the cost effectiveness of your wastewater treatment systems and particularly examine the question of residuals disposal. You see, we have not truly destroyed pollutants anywhere in this country. They still exist, despite what you often see in the news media. We are merely moving them around. We took them out of the water and, in some cases, put them in the air. We have taken them out of the air and, in some cases, put them in the water. Now the sink we are using, whether we like it or not, is the land. There will come a time --and we are rapidly approaching it--when we won't be able to put them in the land, either. So as the regulations become more and more strict, the cost effectiveness of the various alternatives available to industry change. One of the things industry should continually examine is can you save money by becoming a direct discharger and moving your facility outside the jurisdiction of a publicly owned treatment works? You can be certain that whatever the requirements are today, they will be more strict in the future, and if you are planning for a ten or twenty-year time span, you should make the deliberate assumption that whatever effluent limit you have today will be more rigid in those years than they are now. The regulatory process will be more restrictive; there will be more you are told to do than you are now told. You should build that into your long range planning. For the present, can you recover and reuse pollutants now in the sludge, or the wastewater? Can you recycle the water so that you reduce your total water use? And, finally, remember if the pretreatment process works, we have not again destroyed pollutants; we have merely moved them someplace else. The industrial plant site is the place to which we have moved them; instead of a large volume of industrial sludge mixed with a large volume of municipal sludge, we will have little piles of industrial sludge all over the landscape at industrial plant sites. The question then is, what will be done with those little piles of highly concentrated industrial sludge? The chances are for the most complex industries, it's likely to be hazardous. There will have to be some disposal site for hazardous waste. Or you could, I presume, do like some industries have done, merely stack it on your plant site until you go out of business, and then leave it to be disposed of by the government. We have not destroyed it, we have merely moved it. The pre-treatment process merely distributes it over the jurisdictional area of the publicly owned pre-treatment works. Residuals will merely accumulate in smaller quantities, in higher concentrations, in different places. We have not solved the disposal question. Instead of Detroit looking for one site to put municipal sludge, there will be 150 to 200 major industries scrambling all over one another to find industrial sites for the disposal of industrial sludge. You must consider, as an industry, what the ultimate cost may be for that residual, those ashes that you have in the fireplace, that you can't put anywhere else.

EPA-287 (Cin.)
(4-76)

For municipalities, you face some interesting questions. What would be the financial effect of a reduction in your industrial water sales if you sell water as well as treat waste water? Because the effect of pre-treatment requirements, industrial cost recovery and user charges is to encourage industries to reduce their purchases of water by recycling the water within the system. In a similar vein, for those responsible for wastewater treatment systems alone, what would be the effect of a reduction in the volume and constituents of the waste water you do receive? In other words, if industries decide it is more cost effective to recycle or recover the resources and in the process reduce the basis for their industrial rates, their payments to you as a wastewater collector and treater will decline; what effect will that have on the financing of your wastewater collection and treatment system? It is conceivable, if industries are imaginative and innovative in what they do in pre-treatment and resource recovery, that the rates for municipal users will have to be increased to accomodate the reduction in industrial waste discharges because the capitol investment in the system has already been made and the chances are that any reduction in the quantity of wastewater may not be matched by a similar reduction in the annual maintenance and operation cost for the facility. The cities, municipalities and political subdivisions that do treat wastewater and supply water to industries may face some interesting financial problems in the long run. Another question for municipalities is do you really want the long range administrative burden of collection and enforcement for the pre-treatment requirement and the industrial cost recovery funds, as well as the user charges? In other words, do you wish to be somewhere in that chain between the industrial user and the U.S. Treasury to assure that small increments of whatever cost the industrial facility represents gets back to the Treasury?

For those in the academic field, in my view, toxicology is probably the major area for employment opportunities in the years immediately ahead. Nobody knows for sure yet what all the toxic substances are in solids or in wastewater or in sludge--residuals. There are two statutes the full effect of which has not yet been felt--the Toxic Substances Control Act and Resource Conservation and Recovery Act. Are you in your academic programs preparing students to cope with these questions? Industrial wastewater treatment and therefore, to some degree, industrial production processes, may also be expanding fields. That is, are you producing graduates who understand the connection between production processes and the generations of pollutants including those in the residuals? The whole question of solid waste remains to be solved; there will be increasing needs for persons who understand groundwater hydrology and geology, as well as toxic substances. Residuals remain a largely unsolved problem for those interested in the improving of the environment.

As a final observation, I began by saying I was pessimistic as to the chances for innovation as a result of the large volumes of governmental research. I'm also pessimistic as to the future of combined municipal-industrial wastewater treatment. My prediction is that the volume of industrial wastewater discharged to publicly owned systems will decline in the years ahead, and therefore the need for solving combined municipal-industrial wastewater treatment problems will also decline. In other words, when industries are able to identify the full costs of discharging into publicly owned

EPA-287 (Cin.)
(4-76)

treatment works, they will more and more, as they have an opportunity, seek places where they can discharge without having to pay those costs.

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD. BEGIN SECTIONS HERE

PB83-142166

INDUSTRIAL CATEGORICAL PRETREATMENT STANDARDS

R. M. Southworth, P.E.
U.S. Environmental Protection Agency
401 M Street, S.W.
Washington, D.C. 20460

INTRODUCTION

In 1972, Congress passed the Clean Water Act Amendments of 1972 (P.L. 92-500), one of the most comprehensive environmental laws ever enacted. P.L. 92-500 divided effluent limitations from point sources of pollution into three categories: municipal (domestic wastewater), industrial, and toxic. The U.S. Environmental Protection Agency (EPA) was directed to establish uniform national standards, i.e., secondary treatment, for publicly owned treatment works (POTW) and to establish best practical technology economically achievable (BPT) standards for industrial categories. Both sets of standards had to be complied with by July 1, 1977. In addition, EPA was directly to establish best practicable waste treatment technology (BPWTT) standards for POTWs and best available technology economically achievable (BAT) standards for industrial categories, both of which had a compliance date of July 1, 1983. EPA was to also establish toxic pollutant effluent limitations on a pollutant by pollutant basis using a complicated administrative procedure.

Because of that complicated administrative procedure and because of the difficulty in determining which pollutants were toxic, delays occurred in establishing limitations for toxic pollutants. EPA moved slowly, therefore, to establish those limitations.

The Natural Resources Defense Council (NRDC) and other citizen groups sued EPA because of the delay in promulgating toxic pollutant limitations. As a result, a Consent Decree was issued by the U.S. District Court in Washington, D.C., in June 1976, that required EPA to establish BAT limitations, new source performance standards, and pretreatment standards for 65 specified toxic pollutants by December 31, 1979. The compliance date for those limitations and standards was July 1, 1983.

In 1977, Congress passed the mid-course correction to P.L. 92-500, i.e., the Clean Water Act of 1977. The new Act established three categories for industrial pollutants.

Conventional pollutants are defined as biochemical oxygen demand, suspended solids, fecal coliform, pH, and other pollutants specified by EPA.

BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
BEGIN LAST LINE OF TEXT
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

Treatment of those pollutants by best conventional technology (BCT) is required by July 1, 1984.

Nonconventional pollutants are all pollutants not classified by EPA as either conventional or toxic. Treatment by the best available technology is required by 1984.

The new Act specified an initial list of toxic pollutants to which EPA could add or subtract pollutants. That list was based on the 65 pollutants specified in the 1976 Consent Decree. EPA refined the Consent Decree list into 129 specific compounds. The new Act extended the court-imposed deadline for promulgation of toxic pollutants limitations to July 1, 1984, and required treatment by the best available technology by that date.

The BAT toxic pollutant limitations apply to direct discharges, i.e., discharges to a body of water. Similar limitations apply to indirect discharges or discharges to a POTW. EPA is required to establish categorical pretreatment standards by either industrial category or subcategory for indirect discharges. Those standards apply uniformly to all industries within the industrial category or subcategory.

This paper discusses the categorical pretreatment standards currently being developed by the Effluent Guidelines Division, which is in the Office of Water Regulations and Standards. It includes a discussion of the pretreatment requirements in the Clean Water Act of 1977, a discussion of EPA's general pretreatment regulations, and a discussion of the procedure used to establish categorical pretreatment standards. In addition, it discusses a study that is currently being conducted by EPA to determine the fate of toxic pollutants in POTWs.

CLEAN WATER ACT OF 1977

In the 21 major industrial categories, there are many thousands of discharges to POTWs known to cause significant problems by:

- Interfering with POTW operation, i.e., causing fires, corrosion, explosions, hazardous fumes, and system upsets;
- Passing through the POTW.
- Otherwise being incompatible with the POTW, e.g., interfering with sludge disposal.

Section 307(b) of the Clean Water Act prohibits the discharges of pollutants to a POTW that interfere with, pass through, or otherwise are imcompatible with a POTW. EPA is required to define interfere with, pass through, and incompatibility and to establish pretreatment standards that prohibit the discharge of pollutants that violate those definitions. EPA's pretreatment regulations provide information on how to implement Section 307(b).

EPA-287 (Cin.)
(4-76)

PART 403 PRETREATMENT REGULATIONS

General Pretreatment Regulations were published in the Federal Register on June 26, 1978, and were revised on October 29, 1979. Those regulations discussed what is required for a pretreatment program and established two types of pretreatment standards: prohibitive discharge standards and categorical pretreatment standards.

Prohibitive discharge standards apply to all users of a POTW whether the user is subject to national pretreatment standards or to any state or local pretreatment requirements. Those standards are expressed in general terms and prohibit:

- Pollutants that create a fire or explosion hazard in the POTW.
- Pollutants that cause corrosive structural damage.
- Solid or viscous pollutants in amounts that cause obstructions in sewers or interfere with the operation of the POTW.
- Pollutants at a flow rate and concentration known to cause or that may cause interferences with the POTW.
- Heat in amounts that inhibit biological activity in a POTW.

The authority that establishes the local pretreatment program is responsible for establishing specific limits for the prohibitive discharge standards.

Categorical pretreatment standards are national standards established by the Effluent Guidelines Division for industrial categories or subcategories. Those standards specify quantities or concentrations of pollutants or pollutant properties that may be discharged to a POTW. They are in addition to the prohibitive discharge standards and are applied uniformly on a national basis. If categorical standards exist for an industry and that industry discharges to a POTW, the local pretreatment program must require the industrial to meet the categorical standards except under circumstances discussed in the pretreatment regulations, i.e., credits. The procedure used to establish categorical pretreatment standards is discussed in the next section.

CATEGORICAL PRETREATMENT STANDARDS

The Clean Water Act Amendments of 1972 and the Clean Water Act of 1977 both established the principle of uniform national controls for industrial pollution sources and specified that effluent limitations for those sources be based on the technological and economic capabilities of the industries to treat their wastewater. EPA's policy is, therefore, to establish uniform effluent limitations for both direct and indirect discharges. This section discusses the procedure used to establish categorical pretreatment standards for indirect discharges.

The philosophy behind establishing uniform categorical pretreatment standards is that all industries in a category or subcategory should have to

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

treat their wastewater to the same degree of treatment. This prevents industries from "shopping around" to find a location where pretreatment standards are the least stringent and allows EPA to promulgate limitations that are manageable.

Categorical pretreatment standards are technology based standards. They are based on the degree of treatment that can be obtained by different technologies considering the economic impact of those technologies. They are not based on water quality considerations. The fact that the categorical pretreatment standards are not water quality based standards is one reason why those standards can be applied uniformly on a national basis.

The first step in the procedure used to develop a categorical pretreatment standard is to prepare a development document. That document characterizes the industry's wastewater, estimates the amount of wastewater generated, identifies wastewater constituents suspected of passing through or interfering with POTWs, screens wastewater treatment processes, evaluates the feasible treatment processes, and estimates the quality of the wastewater from the treatment processes. Non-water quality environmental impacts, e.g., noise and air, of the feasible treatment processes are then reviewed along with the economic impacts, financial impacts, the age of equipment and facilities involved, the industrial process employed, the engineering aspects of the various types of control techniques, and the space required.

After all of the information is considered, EPA determines which pollutants to include in the standard and the concentration of those pollutants. The categorical pretreatment standards represent, therefore, the prohibition on the discharge of pollutants that EPA determines can be economically achieved by industry considering other impacts. As previously mentioned, those standards are not based on water quality considerations.

The economic impact of the categorical pretreatment standards is a major concern to EPA. Therefore, the feasible treatment options identified in a development document are evaluated both economically and from a financial viewpoint.

In the economic analysis, two cost components are considered. The first is the capital cost or the intitial investment required to install pollution control technology. Capital costs include the cost of planning, designing, and installing the pollution control technology.

The second cost component is the total annual cost of compliance with the standards. The annual cost includes operation and maintenance (O&M) costs of the control technology, e.g. energy costs and sludge disposal costs, and the principal and interest payments on the intitial investment.

Both capital and annual operation and maintenance costs are used to evaluate the economic impact of a control technology. In addition, the financial impact of that technology is considered. The investment requirements for compliance and associated annual costs are compared with balance sheet and income statement information to determine the projected financial status of the plants after all compliance requirements are met. If a plant's

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

estimated profitability after compliance is negative or if the projected debt retirement burden after investment is too high to be paid out of the annual cash flow, that plant is considered a candidate for closure because of the standard.

As previously indicated, information obtained from the economic and financial analyses is reviewed along with other available information before categorical pretreatment samples are promulgated. Management at EPA then determines which pollutants to regulate and the concentration of those pollutants.

CATEGORICAL PRETREATMENT STANDARDS - EXAMPLE

As of this date, categorical pretreatment standards have been promulgated for the electroplating category and proposed for leather tanning, textiles, timber, gum and wood, petroleum and refining, and paint and ink categories. This section illustrates the procedure used to develop categorical pretreatment standards by reviewing the electroplating pretreatment standards.

The development document for the electroplating pretreatment standards indicates that the electroplating industry is a major contributor of toxic pollutants to POTWs. There are approximately 9,400 plants in the industry, most of which are concentrated in heavily industrial areas. Approximately 6,600 of those plants are indirect dischargers and discharge approximately one billion gallons of process wastewater per day to POTWs. The industry's significant pollutants include: chromium, copper, nickel, zinc, cadmium, lead, aluminum, various precious metals, cyanide, and organic compounds. Those pollutants occur in concentrations sometimes exceeding 100 milligrams per liter.

Table 1 contains the categorical pretreatment standards for the precious metals subcategory of the electroplating industry. Different limitations were established for plants that discharge less than 38,000 liters per day than for plants that discharge 38,000 liters or more per day because results of the economic analysis indicated that regulations would most severely impact the industry's low-discharge plants. EPA estimated that compliance with the regulation would cause 737 plants to close, 600 of them small plants in the job shop sector. By using a 38,000 liter/day flow cut-off, EPA minimized the impact of the regulations while still making significant environmental improvements.

Table 2 contains the option considered in settling the 38,000 liter/day flow cut-off. As shown in the table, the closure rate is not very sensitive to flow cut-off, but the percentage of untreated flow is. For example, between a flow cut-off of 38,000 liters/day and 61,000 liters/day, the closure rate decreases only by 1.3 percent, but the percentage of untreated flow doubles from three to six percent. Higher flow cut-off levels follow the same pattern of rapid increase in untreated flow and small decreases in closure rates.

Setting the cut-off level at 38,000 liters/day reduces the closure rate by over five percent while allowing only three percent of the flow to not be

EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

TABLE 1 PRETREATMENT STANDARDS FOR PRECIOUS METALS SUBCATEGORY OF ELECTROPLATING INDUSTRY

Sources Discharging Less than 38,000 Liters/Day

Pollutant or Pollutant Property	Maximum for Any One Day (mg/l)	Average of Daily Values for 30 Consecutive Days (mg/l)
CN,A (cyanide)	5.0	1.5
Pb (lead)	0.6	0.3
Cd (cadmium)	1.2	0.5

Sources Discharging 38,000 Liters or More/Day*

Pollutant or Pollutant Property	Maximum for Any One Day (mg/l)	Average of Daily Value for 4 Consecutive Monitoring Days (mg/l)
Ag (silver)	1.2	0.7
CN,T (cyanide)	1.9	1.0
Cu (copper)	4.5	2.7
Ni (nickel)	4.1	2.6
Cr (chromium)	7.0	4.0
Zn (zinc)	4.2	2.6
Pb (lead)	0.6	0.4
Cd (cadmium)	1.2	0.7
Total Metals	10.5	6.8

* Revised per stipulation.

TABLE 2 FLOW CUT-OFF OPTIONS FOR ELECTROPLATING INDUSTRY

Flow Cut-Off Gallons/Day (liters/day)	Closure Rate (%)	Untreated Flow (%)
None	25.6	0
10,000 (38,000)	20.5	3
16,000 (61,000)	19.2	6
20,000 (76,000)	18.3	8
30,000 (114,000)	17.5	13
40,000 (152,000)	17.5	20

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

treated. EPA believes the closure rate can be reduced even further if small shops in the job shop sector use financial assistance available from the Small Business Administration to finance the needed controls.

In addition to establishing the flow cut-off at 38,000 liters/day, EPA also decided to only regulate cyanide, lead, and cadmium for the low flow shops. Lead and cadmium were regulated because they pose significant human health problems, while cyanide is extremely toxic. These three pollutants have a greater potential to damage the environment than the other pollutants do.

The electroplating categorical pretreatment standards were based on the following control technologies: cyanide oxidation, chrome reduction, precipitation of metals by means of pH adjustment, and solids removal. Many of the industries in the electroplating category already use some of these technologies.

This example illustrates the information collected when developing categorical pretreatment standards and how it is used to establish those standards. The final discussion on the pollutants regulated and the concentration of those pollutants is made by the management at EPA.

POTW TOXIC POLLUTANT STUDY

In 1978, EPA initiated a study on toxic pollutants in POTWs. The purpose of that study is to determine the fate of toxic pollutants in POTWs. Influent, effluent, and sludge samples are being collected at 40 POTWs and are being analyzed for the 129 priority pollutants.

Several factors are considered when selecting a POTW for sampling as part of this study. They include:

- treatment processes
- size
- amount of industrial flow
- type of industrial flow
- POTW operating efficiency
- flow as percent of design capacity
- POTW location.

POTWs selected to date represent the full spectrum of common treatment processes in use today. The biological treatment process in most of those plants is either activated sludge or trickling filter since those processes are most prevalent.

POTW size is measured by design flow. Since the Part 403 General Pretreatment Regulations pertain to POTWs with a capacity of 5 MGD and greater, all of the plants samples in this study are 5 MGD or greater in size. The existing flow at the POTW also had to be 50 percent or higher of the design flow.

TYPING GUIDE SHEET
EPA-287 (Cin.)
4-76)

If possible, only POTWs that meet the secondary treatment regulations were selected for sampling. Since few plants meet those requirements all the time, POTWs with reasonably good operation, as determined by the EPA project officer, are being sampled.

The POTWs sampled in this study have an industry flow from zero to more than 50 percent. We anticipate that all of the 37 industrial categories for which standards are being promulgated by EPA discharge to one or more of the POTWs.

Currently, 27 POTWs have been sampled across the country. Results of the wastewater analyses for 21 of the POTWs have been received and are being evaluated. Results of the sludge analysis for nine of the POTWs are also being evaluated. We expect to publish an interim report with data from 20 of the 40 POTWs by October of this year.

There are currently three options for the use of the data obtained from this study. The first is that the data could be used to either support or not support the categorical pretreatment standards. These data could also be used to support regulations on sludge management. That could also impact the categorical pretreatment standards since those standards may be related to the requirements established for sludge management.

The third option for the use of the data from this study is to support best practicable waste treatment technology (BPWTT) standards for POTWs. Data could be used to determine which pollutants to regulate and to determine the effluent concentrations for those pollutants.

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

PB83-142174

MINIMIZING COSTS BY GOOD FINANCIAL MANAGEMENT

S. Sacks
Synthetic Organic Chemical Manufacturers Association, Inc.
1612 K Street, N.W., Suite 308, Washington, DC 20006

ABSTRACT

There are a number of Federal financial programs that can be used to minimize the cost of pollution control facilities. The Small Business Administration has an Economic Injury Loan Program for pollution control covering requirements for air, water, RCRA, and TSCA as well as other Federal regulations. The direct loans are currently being offered at 8 1/4% and may extend up to thirty years. An alternative, Pollution Control Revenue Bond Program guaranteed by the Small Business Administration can save a company roughly 25% of their financing costs over a period of 25 years over conventional financing plans. The bonds are tax-exempt and guaranteed by the full faith and credit of the U.S. Government. The program is open to the smaller companies that are at a competitive disadvantage with the larger companies. The bond program should be considered for companies seeking sums over $150,000. Companies may also take advantage of tax incentives and tax credits such as the rapid tax amortization program and the Tax Reform Act of 1978.

TEXT

With the prime interest rate at the highest level ever in the history of the country and the inflation rate close to 20%, financing pollution control costs is an extremely difficult task.

For this reason, I want to discuss various important financial assistance programs that you should keep in mind when advising a client about a treatment plant, or helping an industry come into compliance with your local, state and Federal laws or installing a plant.

There are certain tax considerations in regard to pollution control devices from certain sales, use and property taxes that allow industries to pay lower taxes when purchasing pollution control equipment.

Businesses installing pollution control equipment currently may choose between two methods of income tax treatment. Under the first alternative, the corporation chooses to depreciate the pollution control equipment, using any IRS-approved depreciation method. In addition, as a result of the 1978 Tax Reform Act, the company is allowed to take an investment tax credit of 10%, but the credit may not exceed total tax liability, or

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

$25,000 plus 50% of the tax liability in excess of $25,000, whichever is less. Should the allowable amount result in unused credit, this excess may be carried back to the three preceding tax years, and the balance still unused in those years may be carried over to the 7 succeeding tax years. To qualify for the full investment credit, the property or equipment acquired must be depreciable, have a minimum three-year useful life, to be a tangible, integral part of the enterprise's operations, and be placed in operation during the year for which the credit is sought. Structures built to house a necessary component or which are part of a component qualify for credit, although a structure built to provide shelter alone ordinarily does not qualify for credit. Related mechanical equipment also is eligible even if located physically aprat from the business seeking the tax credit. Under the second alternative tax treatment, the firm may elect to take advantage of the special rapid Amortization of Pollution Control Facilities through Section 169 of the Internal Revenue code. The provision was introduced in 1969 to encourage private enterprise to cooperate in efforts to cope with the problems of industrial pollution. As of the Tax Reform of 1978 rapid amortization applies only to plants in operation prior to January 1, 1976, whose facilities were acquired or installed after 12/31/75. Rapid amortization is attractive only at very high discount rates or high inflation rate or in cases where the equipment would otherwise have a useful life greater than twelve years. The 10% tax credit may be taken regardless of whether rapid amortization is used. However, if industrial revenue bonds are used along with rapid amortization, then only a 5% tax credit is allowable. Presently Congress is considering a rapid amortization write-off in three years.

Useful Life	Percent of Cost of Property Qualifying for Credit
Under 3 years	0
3 years, or more but less than 7 years	33 1/3
5 years, or more but less than 7 years	66 2/3
7 years or more	100

Aside from the tax angles for pollution control, there are various Federal financing assistance programs to helf ease the cost of pollution control. The Pollution Control Loan Porgram was provided for in Section 8 of the FWPCA Amendments of 1972 (92-500) entitled "Loans to Small Business Concerns for Water Pollution Control Facilities" and authorizes loans to assist small businesses in adding to or altering their equipment, facilities or methods of operation in order to meet the Water Pollution Control requirements established under the FWPCA. EPA must certify to SBA that the equipment is necessary and adequate to meet their pollution control requirement.

The loan program comes under the SBA Economic Injury Loan Program and during the past fiscal year 100 million dollars was appropriated for the direct loans. Incidentally, only 40 million dollars of this amount was used.

An "economic injury loan" is a loan based on a hardship caused the business as a result of government regulation, namely pollution control requirements, etc. The economic injury loan program is now made up of water and air pollution control requirements, coal mine, health and safety, occupational safety and health, ermergency energy shortage loans, consumer protection loans, and now includes the Toxic Substances Control Act and the Resource Conservation and Recovery Act requirements.

To date the SBA has lent roughly sixty million dollars with the average loan being $125,000. Thus far the largest number of loans has been to electroplaters, with the wood and paper industry second, and food canning third. The direct interest rate is 8 1/4% and may extend for up to thirty years. Loans are made to concerns who are likely to suffer an economic injury without them: Loans have ranged from $5,000 to 4 million. (In cities with over 200,000 people, two turndowns from a bank are required.)

The loan turndown, however, may take any of a number of forms. The interest rate may be too high, the bank may require a very short payback period or the bank may require more collateral than can be met by the applicant. The bank may not want to lend that much money for a nonproductive venture.

There are participation loans and guaranteed loans with SBA and commercial lending institutions, but these rates are considerably higher (participation rate is 1% below the guaranteed rate and the guaranteed rate is 1/2% over the prime rate. Today the prime rate is 19% and so you're looking at 20% money.

The loan program is on a first come first served basis and SBA has tried to improve its image and cut down on paper work. Every SBA office is being made aware of the environmental problems of certain industries.

ELIGIBILITY AND PURPOSE OF LOAN

1. The business has an effluent discharge requiring an NPDES permit. The permit is in essence a contract between a discharger and the government. It regulates what may be discharged and how much. It sets specific limits on the effluent from each source. With a schedule of cutting down on the effluent with a view towards total elimination.

2. The business emits discharges through a sewer line into a (307) publicly owned treatment works, and the city or town requires pretreatment of waste discharge, (the applicant must submit the municipal permit number and receive from the municipal POTW a statement detailing the specific pretreatment requirements).

3. The business plans to discharge into a municipal sewer (307) system through the construction of a lateral or interceptor sewer.

4. The business is subject to the requirements of a State or regional authority for controlling the disposal of pollutants that might affect groundwater (208 requirements).

5. The business is subject to a Corps of Engineers permit for disposal of dredged or fill material (404) from anyone proposing to discharge dredged or fill material into navigable waters of U.S.

6. The business is subject to Coast Guard or State requirements (312) regarding the standard of performance of marine sanitation devices controlling sewage from vessels. All regulated vessels will be required to install a certified device or otherwise meet EPA standards by January 30, 1970.

7. The business is implementing a plan to control or prevent the discharge or spill of oil or other hazardous substances. (Stores oil greater than 1320 gallons above ground and 42,000 below.) (Section 311J of P.L 92-500)

Basically any requirement that is in compliance with Federal Pollution Control Requirements is eligible for the loan program. Air pollution control, toxic substances requirements and solid waste requirements are also eligible.

For purposes of the Small Business Administration, a small business is defined either by the number of employees or sales volume. A business having less than 250 employees is definitely small business. Certain industries can be considered small even though they have as many as 1,500 employees.

Aside from the SBA Economic Injury Loan Program, the Economic Development Administration also has a good loan program for pollution control. The consideration under the EDA program is based on the number of jobs created or saved and whether or not the business is located in an economically depressed area. An advantage of EDA program is that a business need not be considered small. Businesses may also set up a cooperative arrangement for handling the pollution control costs. Currently, the interest rate for EDA loans is 11%.

The Farmers Home Administration also has an attractive loan program that should be consulted in rural areas.

Lastly, I want to tell you about a form of financing which is relatively new and at present the most attractive vehicle for financing pollution control costs.

Public Law 94-305 authorized SBA to guarantee the payments under qualified contracts entered into by existing small business concerns, which are, or are likely to be, at an operational or financing disadvantage with other businesses for the purpose of acquiring pollution control facilities. In other words, the SBA guarantees the payment of 100% of the aggregate to be financed. The act allows the loans to be financed from proceeds of tax-exempt bonds. These bonds thus are rated AAA, and the borrower is able to borrow money at roughly 25% less than a nonrated bond. On a $200,000 issue, it amounts to a savings of $50,000 over the 25-year term.

The purpose of using tax-exempt industrial revenue bond financing for pollution control facilities is to obtain the most advantageous interest rate and repayment terms possible.

In order to qualify for the program, the SBA requires that the applicant must be one which together with its affiliates is independently owned and operated, is not dominant in its field of operation and does not have a net worth in excess of $6 million, and does not have an average net income, after Federal income taxes, for the preceding two years in excess of $2 million and qualifies as a small business concern under section 121.3-10.

The small business concern must be at an operational financing disadvantage with other businesses with respect to the planning, design or installation of pollution control facilities. The applicant small business concern must be in business a minimum of five years, and have a history of profitable operations for any three of the last five years. The small business concern must provide evidence from a Federal, State, or local environmental regulatory authority that the facility is likely to help prevent, reduce, abate or control pollution or contamination.

The repayment period is usually twenty five years. The principal amount to be financed under a qualified contract cannot exceed $5,000,000.

A small business initially requests a loan from a state or local authority empowered to issue the bonds. In most states it is the state economic development agency or business development agency. In other areas bonds are issued directly by municipalities.

The authority, in turn, requests that the SBA guarantee the loan. The SBA, after reviewing the applicant's business qualifications under the program guidelines, agrees to guarantee the loan and reports to the authority. When the authority has several businesses with the SBA approval, it can package a bond issue of marketable size. The issue is marketed through an underwriter, and the proceeds from the issue are made to the businesses.

The loan funds are deposited with an appointed trustee. The businessman can use the proceeds over a three-year period, to finance construction and equipment required to meet environmental control standards, costs of site preparation, and all expenses necessary to begin and supervise construction, including legal and engineering costs. These funds may also be used to pay bond issuance expenses, application fees, establish a reserve fund, and refinance existing debt for a pollution control facility. They may not be used to replenish working capital. Funds are dispersed by the trustee upon receipt of invoices for any of the approved uses.

Additional Requirements

The small business concern is required to submit the following information with its application:

1. SBA Form 912, "Statement of Personal History," on all officers, director, holders of 20 percent or more of the voting stock;

all partners and proprietor of the applicant small business. (This form can be obtained by any local SBA office.)

2. Annual financial statements for the preceding five (5) fiscal years. (Audited statements for the most recent year, or for all 5 years may be required by SBA.)

   a. Standards for Audited and Unaudited Financial Statements

   Financial statements include three basic statements - balance sheet, income statement, and statement of change in financial position. The statements are to be prepared in accordance with generally accepted accounting principles adopted by the Financial Accounting Standards Board (FASB), and have adequate footnote disclosure so as to make the statements not misleading.

   When audited statements are required, such audits are to be made by an independent auditor in accordance with generally accepted accounting standards.

3. Interim financial statement (not older than 90 days).

4. Two years pro forma cash flow after giving effect to the financing applied for.

5. Most recent financial statements on all affiliates listed in item No. 4 of the application.

6. A brief history of the applicant small business, including type of business, method of operation, data established, ownership composition, and background experience of key management personnel.

7. Copy of the appraisal of the value of other collateral (if required) tendered as additional security for the financing (including the existence and amount of outstanding liens thereon).

8. Copy of bid proposals or estimates including plans and specifications for the pollution equipment or property, construction/installation, etc.

9. An in-furtherence certificate from the appropriate environmental regulatory authority stating essentially that the pollution control facility, when completed in accordance with the plans and specifications, will help prevent, reduce, abate, control noise, air, or water pollution or contamination by removing, altering, disposing or storing pollutants, contaminants, wastes, or heat, or property used for the collection, storage, treatment, utilization, processing, or final disposal of solid or liquid waste.

10. An opinion from the consulting engineer/architect responsible for the design of the facility, that the facility, when completed, will meet the required pollution control standards or regulations.

While not specifically required from each applicant, sound judgment dictates that:

a. On a case-by-case basis, SBA may require third party guarantees and/or additional (other than the pollution facility) tangible security, and

b. When outside contractors are used for construction and/or installation of the facility the applicant may wish to consider the advantages of a surety bond.

The Qualified Sponsor:

Because of its close financial relationship to the applicant, the qualified sponsor will usually be the bank of account of the small business concern. In addition to completing Part II of the application (SBA For 1136) and assisting the small business concern prepare its part of the application for SBA assistance, the sponsor is asked to prepare a complete financial and credit analysis of the small business concern (including affiliates) and to issue an opinion and recommendation as to the applicant's creditworthiness for the financing in accordance with its and SBA's established credit criteria and requirements (section D, below). This opinion, analysis and recommendation is made with no liability on the part of the sponsor. (See Appendix I) While SBA relies upon the analysis and recommendation, final determination whether or not to issue its guarantee rests with SBA.

The demand for this type of financing is extremely high. In 1979 industry spent 7 billion dollars in capital expenditures for pollution control facilities with half of that figure being financed with IDBs. I am sure in 1980 the demand for pollution control facilities will continue.

With credit as tight as it is, and the cost of money at an all time high, it is almost the only alternative left for financing pollution control facilities. Hopefully the rate which was 6 1/4% in August, 7 1/2% in December, 9% in February and 9.2% in March will start to come down, but your guess is as good as mine.

For financing pollution control facilities the two best methods are the pollution control revenue bonds guaranteed by the Federal government and the pollution control loan program.

PB83-142182

BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

COMPATIBILITY ASSESSMENT OF MUNICIPAL/INDUSTRIAL WASTEWATERS FOR COMBINED BIOLOGICAL TREATMENT*

by

A. W. Busch
Environmental Engineering Consultant
7223 Lavendale Circle
Dallas, Texas 75230

ABSTRACT

There are numerous chemical and hydraulic aspects of biological treatment of combined municipal and industrial wastewaters. Compatibility is effected by qualitative and quantitative characteristics of the wastes involved. Assessment should include reaction rates, phase distribution of organics, concentration effects, hydrographs and relative volumes, transport time effects and nature of sludges produced. When compatibility assessment is properly done during process design, combined treatment is frequently not the best alternative. Because of legislation and regulations developed since 1970, combined biological treatment is less attractive now than ever. Separate treatment is increasingly the obvious method of choice where a choice can be made.

INTRODUCTION

Combined treatment of municipal and industrial waste waters is largely a post World War II issue. In fact, the first 20-year index (1928-48) of what is now the Journal of the Water Pollution Control Federation lists no articles under combined or joint treatment. The next 10-year index (1949-58) shows 58 listings under "combined disposal."

These numbers indicate that combined treatment became a "high-ground" or "motherhood" position in engineering practice, plus, of course, reflecting the real-world fact of urban industrial locations. Many smaller towns and cities actively solicited industrial siting by offering combined treatment as an inducement. Clearly, the ground rules have changed since 1970.

---

*Presented at Conference on Combined Municipal/Industrial Wastewater Treatment, University of Texas at Dallas, Richardson, Texas, March 25-27, 1980

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

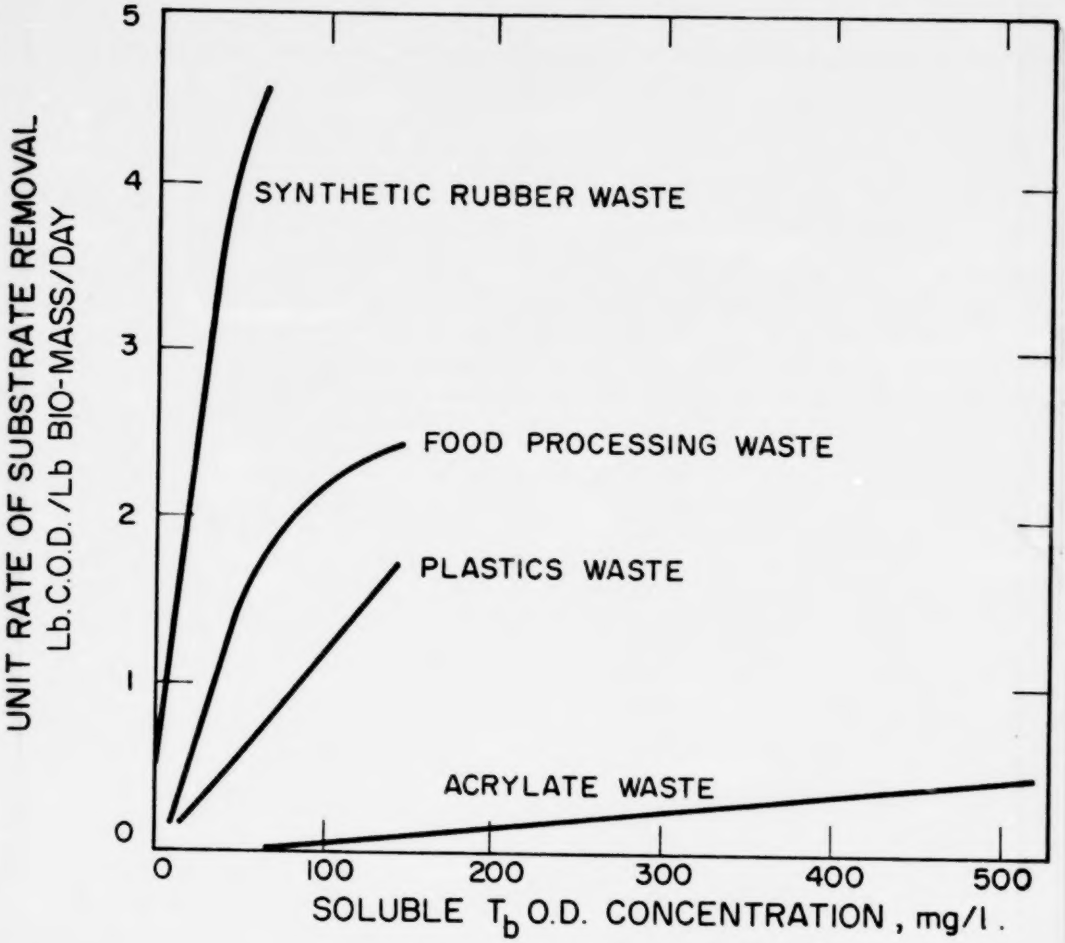


FIG. 1 UNIT RATES OF SUBSTRATE REMOVAL FOR VARIOUS INDUSTRIAL WASTES SHOWING LINEAR PORTION OF CURVES[2]

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

Perhaps the best indication that combined treatment is not a panacea and, in fact, may be an undesirable approach, is that EPA personnel spent 6 years in developing and promulgating General Pretreatment Regulations [1] as required by PL 92-500 in October, 1972. EPA has, of course, labored under a succession of increasingly stringent environmental laws addressing toxic and hazardous pollutants which had to be accommodated by pretreatment regulations. Nonetheless, it is disappointing to find BOD listed as a "material" when, in fact, BOD represents only a parameter of variable and even questionable significance in process and system design [2].

COMPATIBILITY

In setting out pretreatment requirements for industrial wastes discharged to a publicly owned treatment works (POTW), EPA was required to address incompatibility effects [1]. EPA chose to use conventional biological treatment systems designed to achieve secondary treatment effluent standards as the basis for assessing incompatibility effects. EPA further extended its assessment to include ultimate fate of contaminants, especially toxic pollutants, in sludge disposal and air pollution questions.

This approach infers that there are few POTW's receiving industrial wastes which were designed for the combined wastes and this may be correct. However, subsequent papers at this conference seem to offer case histories of recent designs based on combined treatment.

This paper is intended to set out some of the factors pertinent to compatibility assessment of combined wastes as a basis for process and system design. Factors addressed herein are reaction rates, phase distribution of organics, concentration effects, hydrographs and relative volumes, transport time effects and nature of sludges produced.

REACTION RATES

Reaction rate differences for various components of combined wastes represent a major factor in design economy. Because all wastes must be detained long enough for the slowest component to react, combined systems are almost inevitably larger than separate plants would be in aggregate. Figure 1 shows typical rates for several industrial wastes. A mixture would be controlled by the slowest rate. Therefore, a first step in compatibility assessment should be definition of reaction rate characteristics.

PHASE DISTRIBUTION OF ORGANICS

Biological treatment is needed only for the bacterial conversion of dissolved organics to cells, carbon dioxide and water. (Other intermediate or end products are possible.) Many municipal wastes contain little dissolved organics after spending hours or days in a self-seeded tubular reactor called a sewer. Figure 2 shows that in many cases only effective solids separation is required to meet secondary effluent standards. Numerous, possibly the majority of, biological treatment plants receiving

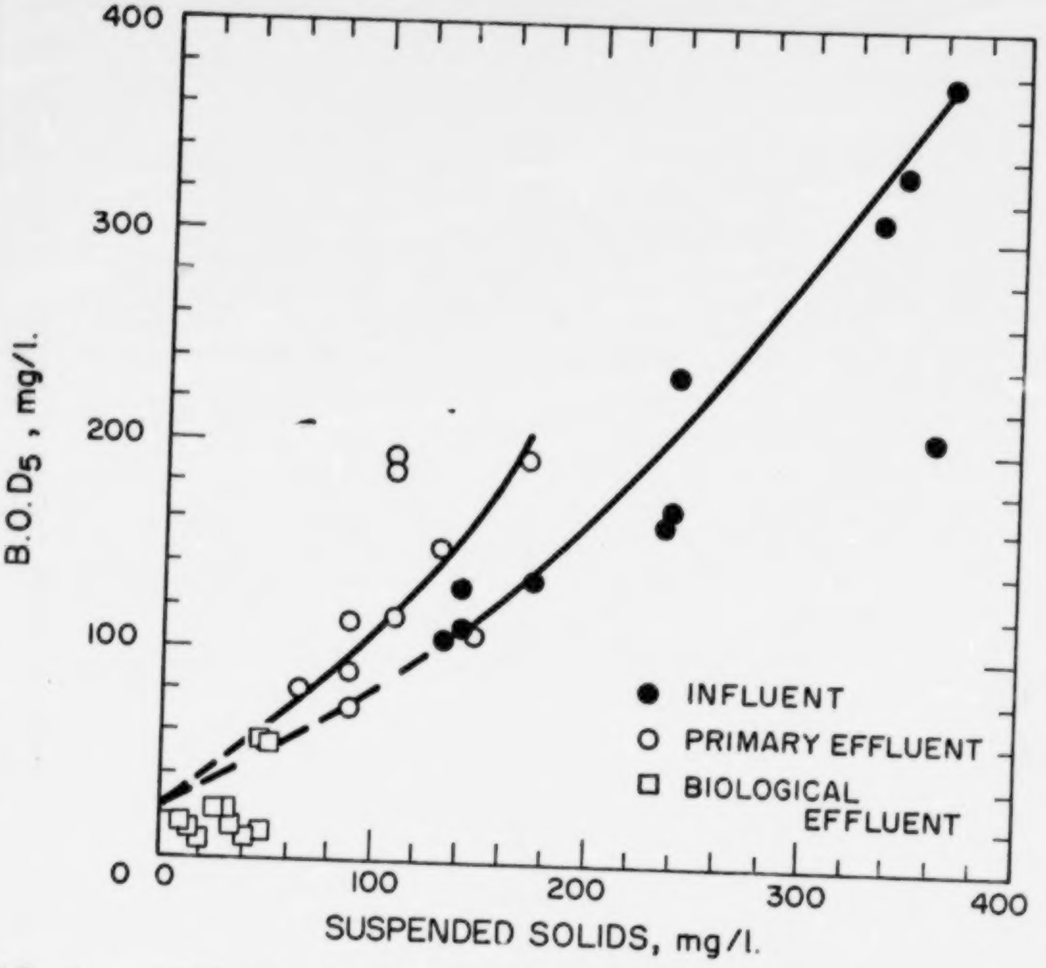


FIG. 2 B.O.D$_5$ AND SUSPENDED SOLIDS DATA FOR MUNICPAL WASTE WATER FROM TEN ANNUAL REPORTS OF SEPARATE PLANTS[2]

EPA-287 (Cin.)
(4-70)

only, or predominately, municipal wastewaters serve only to make anaerobic influent aerobic and to solubilize particulate organics for subsequent (partial or complete) bacterial conversion.

Figure 3 shows a conceptual treatment scheme, using established technology components, for municipal wastes or combined wastes low in dissolved organics when entering the treatment system. This is not applicable for combined wastes high in dissolved organics.

CONCENTRATION EFFECTS

Concentration effects are well addressed in EPA's pretreatment regulations and have been the subject of numerous articles in our literature. Most concern is directed at toxic substances or ions, whether biodegradable or not. In fact, Figures 4 and 5 show that bacterial systems have a potential for assessing concentration effects in terms of toxicity [3].

Mass culture processes such as activated sludge have a capacity for removing certain species of toxic ions, such as metals, and can intentionally be used for this purpose, provided sludge disposition can accommodate the presence of toxic ions. Whereas separate industrial wastewater treatment systems can often be managed from this perspective, combined wastewaters produce much more sludge of a different nature and are not as amenable to use of this unique capacity. This is addressed further under the subject of nature of sludges.

HYDROGRAPHS AND RELATIVE VOLUMES

Two truisms exist here: (1) average flow never exists without equalization and (2) equalization is greatly under-utilized in municipal or combined municipal industrial treatment.

Figure 6 shows a few of the infinite hydrographs all producing the same calculated average rate of flow and/or load. Figures 7, 8 and 9 show how municipal flows could be equalized for application in the Figure 3 flowsheet. Conventionally, of course, equalization of sorts is provided by sizing treatment components for peak flow rates. This is expensive, limits innovation and is really the reason for the various "efficiencies" established for treatment processes although reflecting only system design deficiency [2].

A further aspect of hydrographs for industrial wastes in combined treatment is that they may not be continuous, and thus critical organic components may be only intermittently available to maintain microorganisms needed for their conversion.

Obviously, relative volumes of municipal and industrial wastes may range from a preponderance of one in large cities to the other in a single industry, small town. This factor can be overriding in process and system design.

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
DROPPED HEAD BEGIN SECTIONS HERE
CENTER OF PAGE
TOP OF IMAGE AREA

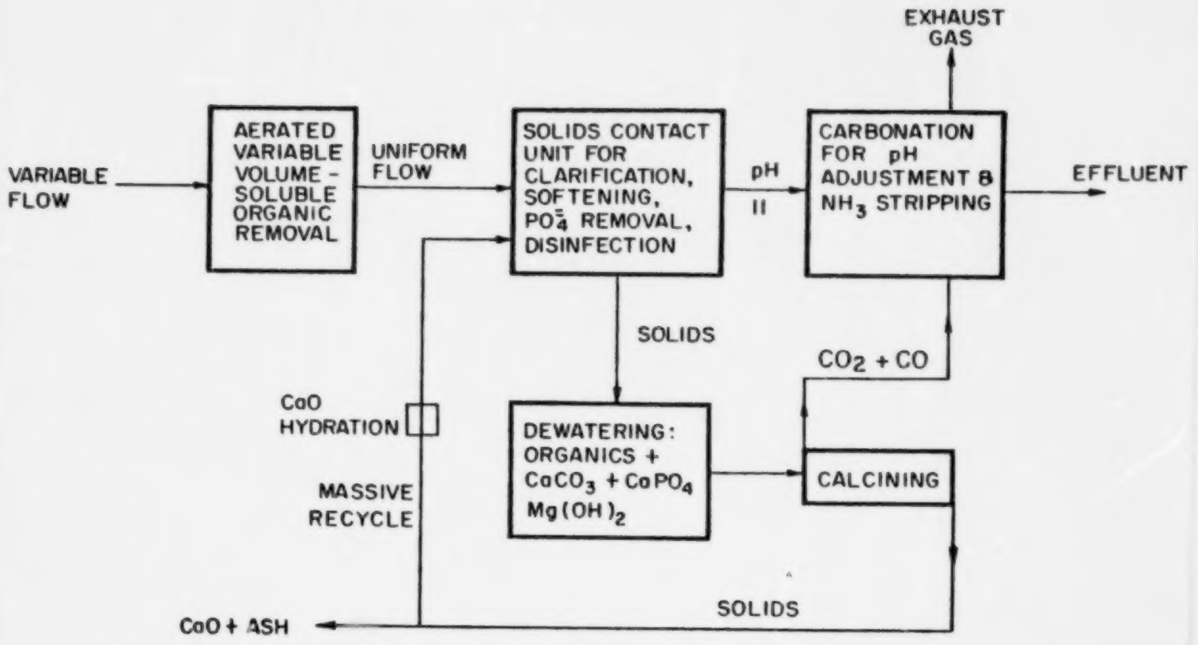

VARIABLE FLOW
AERATED VARIABLE VOLUME - SOLUBLE ORGANIC REMOVAL
UNIFORM FLOW
SOLIDS CONTACT UNIT FOR CLARIFICATION, SOFTENING, $PO_4^{\equiv}$ REMOVAL, DISINFECTION
pH 11
CARBONATION FOR pH ADJUSTMENT & NH_3 STRIPPING
EXHAUST GAS
EFFLUENT
SOLIDS
CO_2 + CO
CaO HYDRATION
MASSIVE RECYCLE
DEWATERING: ORGANICS + $CaCO_3$ + $CaPO_4$ $Mg(OH)_2$
CALCINING
SOLIDS
CaO + ASH

FIG. 3 SCHEMATIC OF MUNICIPAL WASTE WATER TREATMENT BY AERATION, LIME SOFTENING, STRIPPING AND CARBONATION[2]

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUS TRATIONS
3/4"
PAGE NUMBER

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

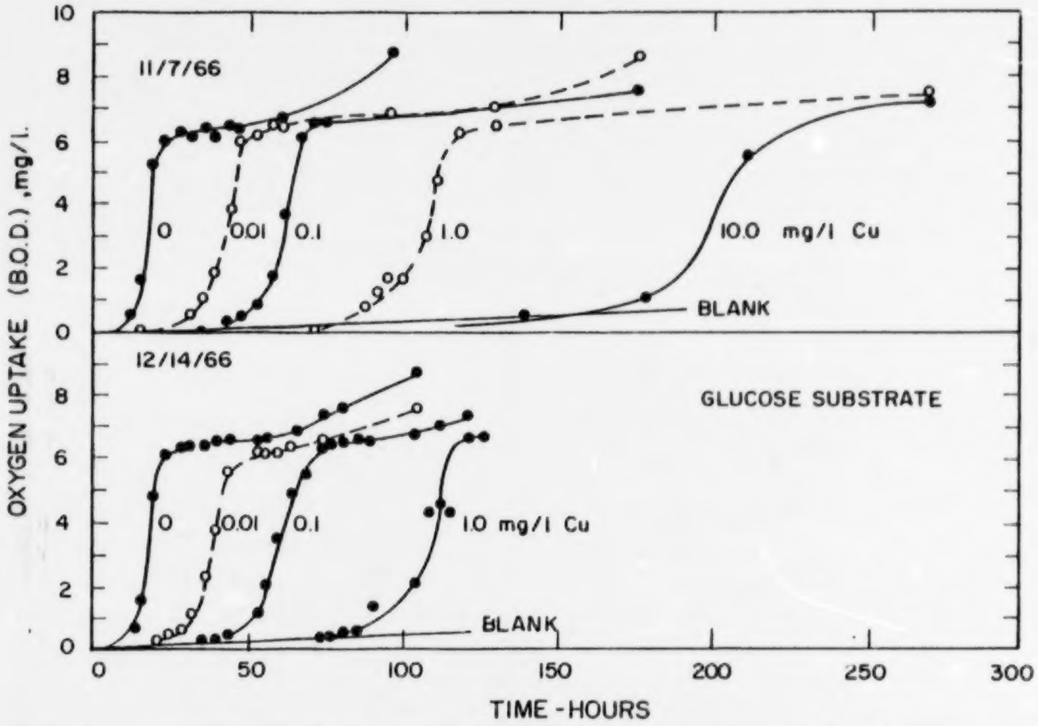


FIG. 4 EFFECT OF INCREASING COPPER CONCENTRATION ON OXYGEN UPTAKE WITH TIME FOR GLUCOSE IN THE BOTTLE SYSTEM (de Bruin, 1966[2])

BEGIN LAST LINE OF TEXT
3/8"
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

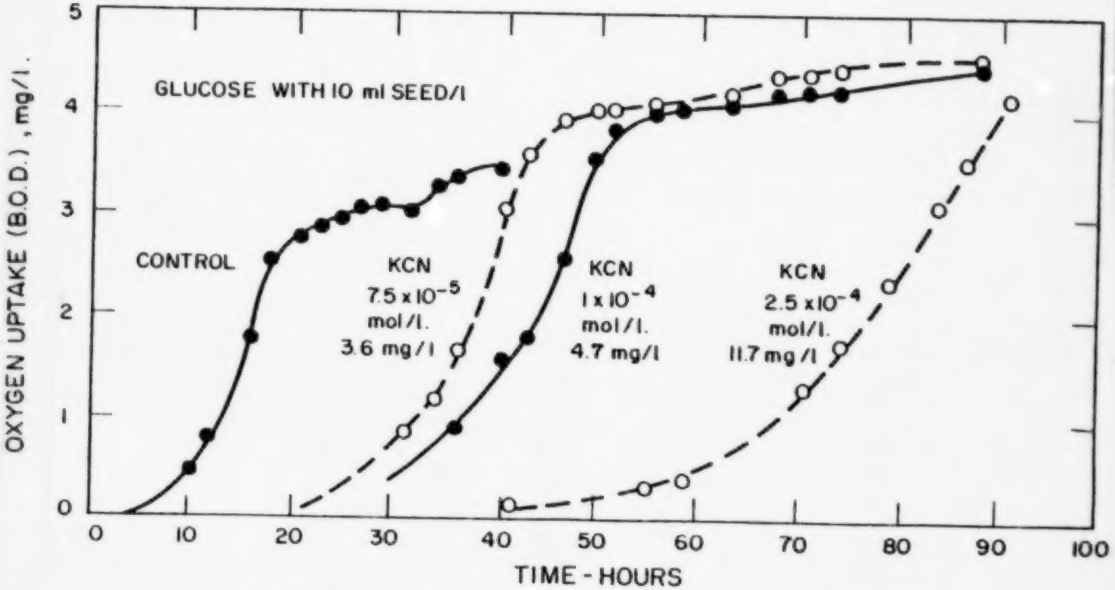


FIG. 5 OXYGEN UPTAKE VS. TIME FOR INCREASING KCN FOR ONE SEED CONCENTRATION IN THE BOTTLE SYSTEM (Zintgraff and Ward, 1969[2])

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

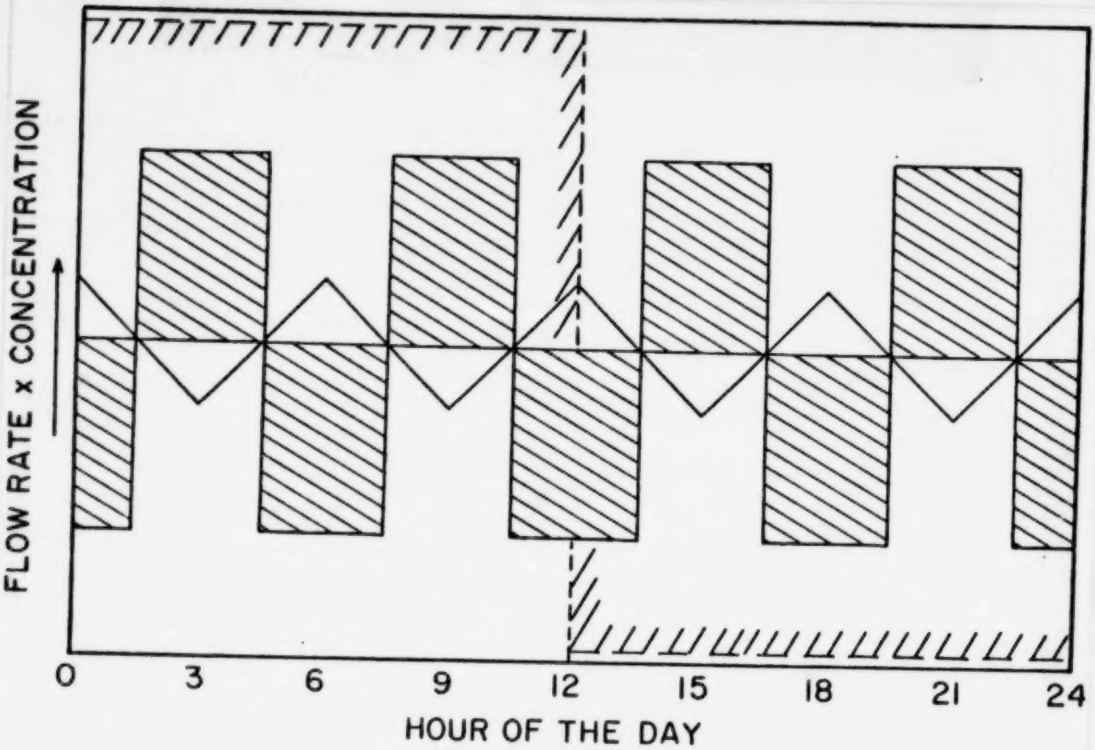


FIG. 6 - COMPARISON OF DIURNAL FLOW-CONCENTRATION PRODUCTS TO AVERAGE VALUE

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER
EPA-287 (Cin.) (4-76)

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

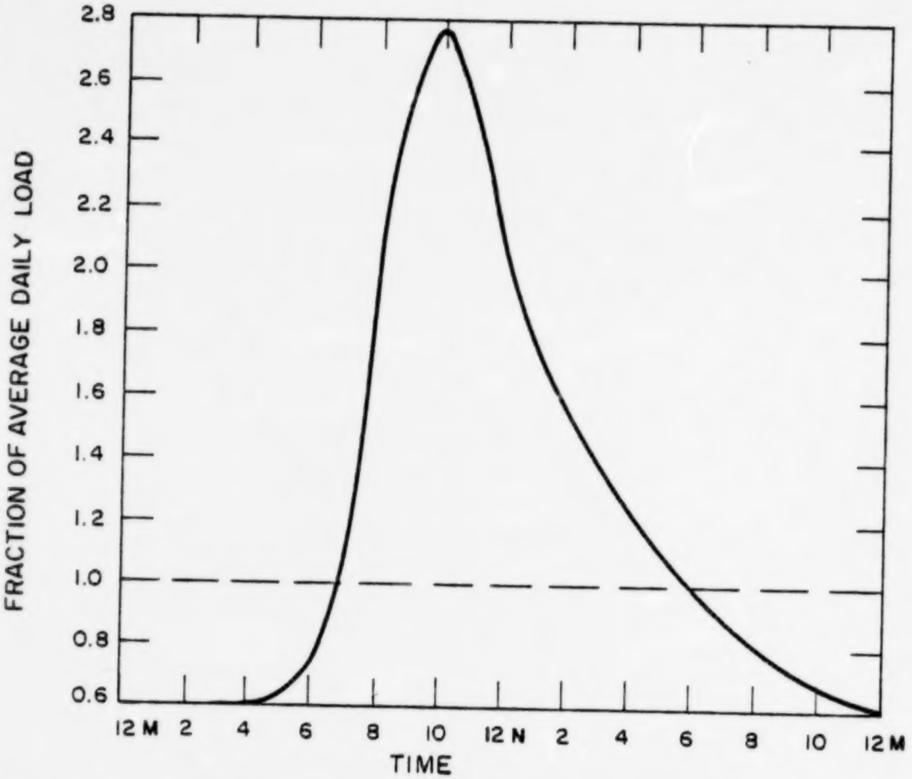


FIG. 7 TYPICAL AVERAGE DIURNAL VARIATION IN ORGANIC LOAD OF MUNICIPAL WASTE WATER[2]

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER
EPA-287 (Cin.) (4-76)

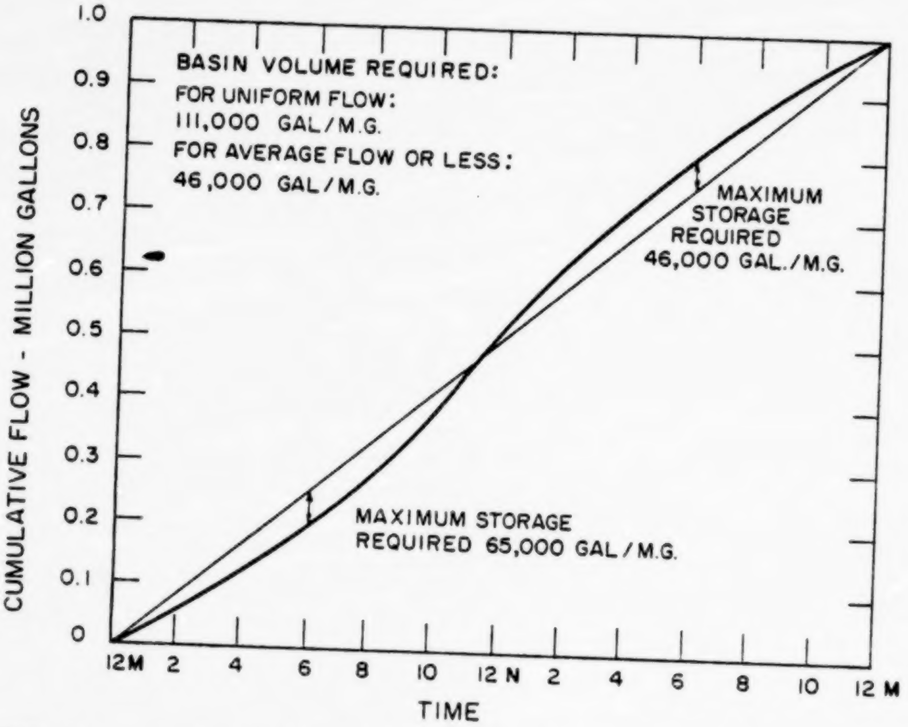


FIG. 8 MASS DIAGRAM FOR TYPICAL DIURNAL FLOW OF MUNICIPAL WASTE WATER SHOWING VOLUME OF AERATED EQUALIZATION BASIN REQUIRED TO ACHIEVE UNIFORM DISCHARGE TO SUBSEQUENT TREATMENT [2]

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

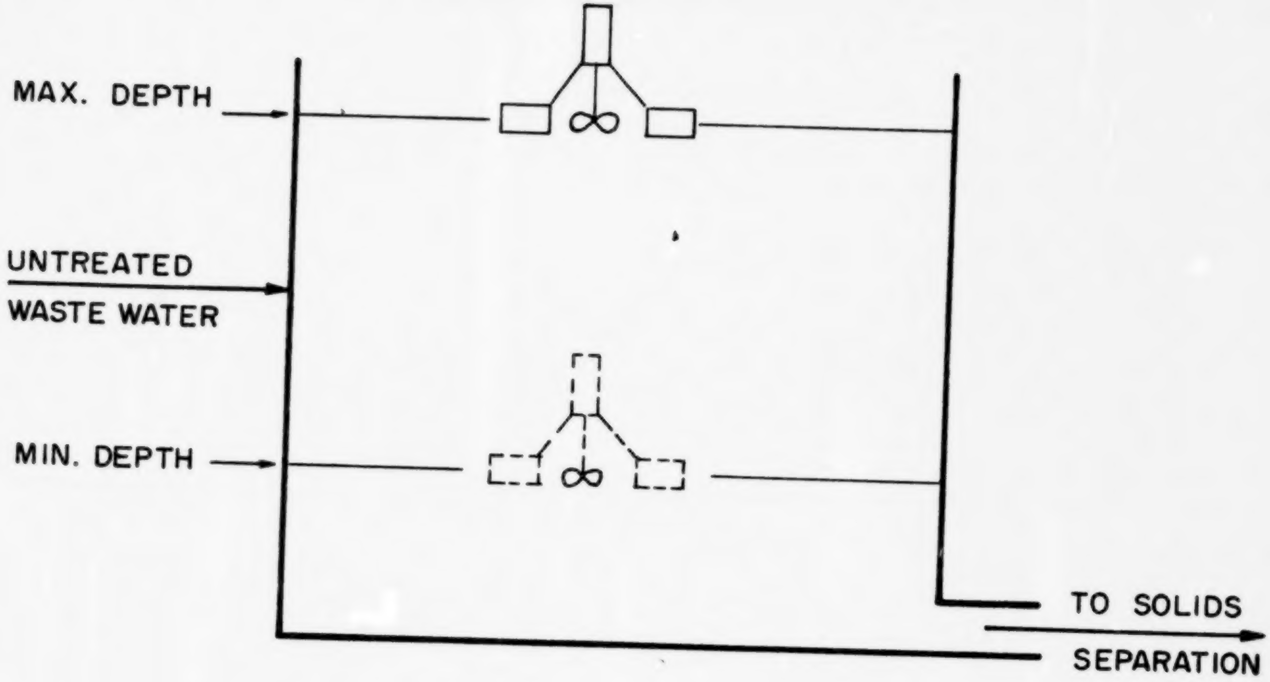

MAX. DEPTH
UNTREATED
WASTE WATER
MIN. DEPTH
TO SOLIDS
SEPARATION

FIG. 9 SCHEMATIC OF VARIABLE VOLUME AERATED EQUALIZATION BASIN FOR MORE UNIFORM FLOW TO MUNICIPAL WASTE WATER TREATMENT SYSTEM[2]

TRANSPORT TIME EFFECTS

As noted earlier, sewers are self-seeded tubular reactors for municipal wastes and for some industrial wastes such as food processing, in particular. Generally as treatment facilities become larger, as is often the case for combined treatment, transport times become longer. The impact of transport time on wastewater characteristics can be significant. For easily degraded wastes, such as food processing, oxygen demand can be increased in both rate of exertion and in total amount by anaerobic transport conditions. Inorganic components such as nitrates and sulfates are reduced and must be re-oxidized in the treatment process.

An added dimension of transport time which must be evaluated is infiltration. Some of the early combined treatment collection systems proposed in the Houston area included truly phenomenal infiltration allowances.

NATURE OF SLUDGES PRODUCED

The widest range of differences in sludges is found between waste-activated sludge from treatment of soluble organic industrial wastes and a mixture of primary and waste-activated sludge from municipal wastes, both in nature and amount.

Industrial waste-activated sludge is stable and can be conveniently placed in deep anaerobic/aerobic ponds or tanks because of the slow rate of release of reduced decomposition products [2]. The concept of aerobic digestion (with, say, 10 days detention) is not applicable to such industrial waste-activated sludges from systems with solids residence times of 10 to 50 days. However, this can be considered as a reservoir of acclimated organisms available in the event of a process breakdown.

In contrast, mixed municipal sludges are highly putrescible, containing a large fraction of organic matter other than micro-organisms. Aerobic decomposition will continue at significant rates if aerobic digestion is provided. Anaerobic decomposition will usually be too vigorous to use anerobic/aerobic ponds or tanks without scum and odor problems.

SUMMARY AND CONCLUSIONS

EPA's difficulties with defining incompatibility effects of combined biological treatment are due to complex legislative requirements, aggravated, at least to some extent, by lact of compatibility assessment during design, especially prior to 1972.

Generally speaking, the concept of combined biological treatment is less attractive now than ever. While individual cases can be cited where mutual advantages can be, and have been, shown, separate treatment is increasingly the obvious method of choice where a choice can be made.

REFERENCES CITED

1. General Pretreatment Regulations for Existing and New Sources of Pollution, *Federal Register*, Monday, June 26, 1978, Part IV.

2. Busch, A. W., *Aerobic Biological Treatment of Wastewaters--Principles and Practice*, Gulf Publishing Company, P. O. Box 2608, Houston, Texas 77001, 1971.

3. Busch, A. W., "A Bioassay Technique for Relative Toxicity in Water Pollution Control," presented at the 51st Annual Conference, Water Pollution Control Federation, October, 1978, Anaheim, California.

PB83-142190

BIOLOGICAL INHIBITION SCREENING OF INDUSTRIAL WASTEWATERS

E. L. Stover Ph.D., P.E.
Metcalf & Eddy, Inc.
Boston, Massachusetts 02114

ABSTRACT

Feasibility investigations for assessment of the biological treatability of industrial wastewaters should initially include a program for characterization of the wastewaters with respect to expected flows and loads. Historical data should be reviewed when available, and routine chemical analyses as well as some specialized analyses should be conducted. The specialized analyses should center around possible inhibition or toxicity problems. Quantitative assessment of inorganic and organic compounds possibly causing inhibition problems by atomic absorption and gas chr[illegible]ograph-mass spectrophotometer analyses is a time consuming and expensive proposition. A simpler method of inhibition screening in terms of required analyses time and expense would be to conduct bioassay type procedures. A simple and inexpensive microbiological inhibition screening test procedure can be conducted by treatment plant personnel at municipal plants receiving industrial wastewater discharges to provide estimates of the threshold inhibition levels to both the carbonaceous and nitrification reactions. This procedure consists of adding different dilutions of wastewater to a series of BOD bottles containing the appropriate seed source (carbonaceous or nitrifying) and monitoring the respective respiration rates. The factors affecting this inhibition screening procedure and important experimental design considerations are presented along with results from inhibition testing of various industrial wastewaters for both carbonaceous removal and nitrification. This test procedure can be employed to provide valuable screening information relative to biological treatment, as well as providing monitoring for problem assessment and changes in the daily operations of treatment facilities.

INTRODUCTION

The possible presence of inhibitory or toxic compounds to biological treatment processes warrant concern where significant quantities of industrial wastewaters are discharged into municipal systems. Wastewater discharged by industries may be quite different from municipal wastewater, and extreme care must be taken to ensure that these wastewaters do not impede or prevent proper operation of the treatment processes. The presence of industrial wastewaters make the behavior of the treatment processes less

EPA-287 (Cin.)
(4-76)

predictable and may necessitate the selection of completely different processes to ensure adequate treatment. Both the flow and loading characteristics may differ significantly, and slug discharges become a potential problem. These effects become more significant as the total proportion of industrial wastewater increases. Industrial wastewaters are subject to change with process modifications and production of new and different types of products. Rigid controls may result in the exclusion of contaminants that are toxic or inhibitory to the treatment processes.

Biological treatment systems, such as activated sludge processes, that are designed and operated to treat industrial or combined municipal and industrial wastewaters can receive a variety of inorganic and organic compounds. Certain types of these compounds, depending on factors of concentration, environmental conditions and sudden changes in environmental conditions, antagonistic effects, and concentration of biomass within the system, are able to reduce or stop the biological oxidative assimilation rates due to inhibition or toxicity. Environmental conditions necessary for growth of the nitrifying bacteria are more specific than those of most of the heterotrophic bacteria responsible for carbonaceous oxidation. Parameters that require particular attention are the total applied loadings (food-to-microorganism ratio), sludge age, or growth rate, temperature, dissolved oxygen concentrations, pH, and inhibitory or toxic materials.

Certain heavy metals and organic compounds are known to be toxic to microorganisms, and inhibitory or toxic concentration levels have been documented in the literature. It has been shown that microorganisms can adapt to inhibitory substances when they are consistently present at concentrations higher than cause toxic effects in slug discharges which can result in industrial and municipal treatment systems due to dumps, accidental discharges, and stormwater runoff and inflow. The rate and change of magnitude of environmental conditions can be almost as critical to the biological process as toxic materials. Changes in temperature, pH, and dissolved oxygen levels can cause inhibition and reductions in biological activity.

Chemicals may react with microbial population by a variety of mechanisms to cause inhibition of cellular functions and/or destruction of cellular components vital to cell function. Presence of heavy metals can result in the occurrence of a variety of abnormalities from deactivation of DNA and RNA to interference with cell wall synthesis. The germicidal qualities of halogen compounds, such as chlorine, have been employed for microbial disinfection for some time. Certain phenolic derivatives act to disrupt cell membranes and inhibit oxicase enzymes associated with surface membranes. Alcohols can cause inhibition of respiration and phosphorylation. Hydrogen ions in high concentrations can displace essential ionic species, such as Na^+ and CA^{++}, from the adsorption sites on the cell, and hydrolytic reactions involving hydrogen or hydroxyl ions can produce damage to the microbial cell.

Inhibition of the nitrification process can occur by interference with the general metabolism of the cell or with the primary oxidative reactions. Inhibition of primary oxidation reactions can be caused by competitive effects or metal chelating agents such as thiocyanide, thiourea, and allylthiourea. The general metabolism of the microorganisms can be inhibited by

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

compounds such as quinacrin, rivanol, and quinine. Cytochromes are adversely affected by cyanide, chlorate, and methyl urethane. Phenol, phenolic compounds, cresol, and halogenated solvents are also potentially toxic materials to nitrification.

It is not easy to distinguish which type of biological inhibition is occurring, especially in a wastewater treatment system. What is important is screening or assessing the potential for and occurrence of inhibition in the biological wastewater treatment system. Industrial wastewater discharges should be given special consideration and subjected to screening procedures.

Feasibility investigations for assessment of the biological treatability of industrial wastewaters should initially include a program for characterization of the wastewaters with respect to expected flows and loads. Historical data should be reviewed when available, and routine chemical analyses as well as some specialized analyses should be conducted on several wastewater samples. The specialized analyses should center around possible inhibition or toxicity problems. Quantitative assessment of inorganic and organic compounds known to cause inhibition problems by atomic absorption and gas chromatograph-mass spectrophotometer analyses would be a time consuming and expensive proposition. A simpler method in terms of required analyses time and expense would be to conduct bioassay type procedures with a population of appropriate bacteria. This type of procedure would provide a valuable screening tool, yielding information on the effects of the total wastewater constituents on biological treatment.

Toxicity has been traditionally measured from lengthy bioassay procedures by subjecting a reference population of organisms to the substance in question. Comparison on the basis of such parameters as survival and metabolic activity are made with a control population of the same reference organism. Organisms commonly employed for assessment of toxicity of water pollutants are fish, macroinvertebrates and bacteria.

Methodologies for use of bacterial cultures in aquatic bioassay measurements have not been sufficiently developed due to the difficulty of quantifying an easily measurable response of the bacteria. Biological activity responses that have received the most attention include oxygen uptake, adenosine triphosphate (ATP) and dehydrogenase. Changes in oxygen uptake, ATP and dehydrogenase activities with concentration of toxic substance have been documented, but development of successful quantifiable relationships is difficult. Dissolved oxygen probes, Warburg respirometer and similar respirometer equipment make this method of activity response measurement appealing. Measurement of cellular ATP has been found to provide valuable indication of viable biomass and biomass activity. Biological activity response has been monitored by the use of 2,3,5-triphenol tetrazolium chloride as an indicator of dehydrogenase.

Simple and inexpensive microbiological inhibition bioassay type screening tests employing the oxygen uptake approach can be conducted by treatment plant personnel to provide estimates of the threshold inhibition levels to biological treatment of various wastewaters for both carbonaceous and nitrification reactions. This procedure consists of adding different dilutions

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

of the wastewater to a series of BOD bottles containing the appropriate biological seed source (carbonaceous or nitrifying microorganisms) and monitoring the respective respiration rates. This test procedure does not provide information relative to the nature of the microbiological inhibition occurring or the specific compound (s) causing inhibition, but it can be employed to provide valuable screening information relative to biological treatability, as well as provide a monitoring tool for problem assessment and changes in the daily operations of treatment facilities. The factors affecting this inhibition screening procedure and important experimental design considerations along with results from inhibition testing of wastewaters for both carbonaceous removal and nitrification are presented.

MATERIALS AND METHODS

The microbiological inhibition testing procedure described by Marks (1) to detect, under a set of defined conditions in BOD bottles, the threshold inhibition level for carbonaceous biological oxidation of a compound or wastewater was modified to provide information on the threshold inhibition levels of both carbonaceous and nitrogenous oxidation. The threshold inhibition levels of the compound or wastewater are defined as the lowest concentration of that compound or wastewater that causes a reduction in the carbonaceous biological oxidation rate for carbonaceous inhibition and a reduction or ceasing of ammonia-nitrogen oxidation for nitrification inhibition. The information developed from this test procedure can be useful as a guideline for determining the effects that a compound or wastewater may have on a biological wastewater treatment system.

The pH of the wastewater sample to be investigated is first checked and adjusted if necessary to pH 7.0 to 8.0 to provide a proper environment during the incubation period. Next a series of dilutions of the wastewater sample are prepared in BOD bottles, as shown in Table 1. The dilution water is prepared in accordance with the procedure described in "Standard Methods for Examination of Water and Wastewater." (2)

During nitrification inhibition screening experiments ammonia-nitrogen is added to the control bottle to provide a controlled level of dissolved oxygen depletion that will reduce the dissolved oxygen level in the BOD bottle by approximately 50 percent of the saturation value of 9.2 mg/l at 20°C. Ammonia-nitrogen is added to the other BOD bottles as required to provide excess ammonia-nitrogen above that required for synthesis during BOD exertion. The ammonia-nitrogen additions should provide around 5 mg/l of excess nitrogen above that required for synthesis reactions. The amount to be added can be estimated from historical wastewater characteristics or by characterizing the wastewater prior to inhibition screening. The biological culture added to each bottle must contain viable nitrifying microorganisms from an existing nitrification facility or developed during pilot biological treatment investigations.

During carbonaceous inhibition screening experiments six ml of 300 mg/l glucose stock solution are added to all the BOD bottles instead of ammonia-nitrogen as indicated in column 5 of Table 1. Biological oxidation level in

TABLE 1. PREPARATION OF BOD BOTTLES FOR INHIBITION SCREENING (NITRIFICATION)

Bottle No.	Wastewater volume, ml	Percent wastewater volume	Biological culture volume, ml	[illegible]0 mg/L ammonia-nitrogen solution volume, ml	Dilution water volume
1[1]	0.0	0.0	5	1.0	(3)
2	0.01	0.003	5	(2)	
3	0.1	0.03	5	(2)	
4	1.0	0.3	5	(2)	
5	3.0	1.0	5	(2)	
6	6.0	2.0	5	(2)	
7	10.0	3.3	5	(2)	
8	30.0	10.0	5	(2)	
9	60.0	20.0	5	(2)	
10	100.0	33.3	5	(2)	
11	200.0	66.7	5	(2)	
12	250.0	83.3	5	(2)	

1. Bottle No. 1 = Control.
2. Ammonia-nitrogen added as required to provide an estimated 5 mg/L concentration available for nitrification.
3. BOD dilution water is added to each bottle as required to fill BOD bottles (total volume = 300 ml).

the BOD bottles by approximately 50 percent of the saturation value of 9.2 mg/l at 20° C. The biological seed culture for this experiment should be a viable heterogeneous culture from an existing treatment facility or developed from domestic sewage.

The bottles are aerated by connecting the filled bottles to an empty BOD bottle with a piece of PVC pipe and shaking the two bottles to bring the dissolved oxygen level close to saturation. The empty BOD bottle can be filled with oxygen prior to aeration to enhance the aeration process. Following aeration the initial dissolved oxygen levels in each bottle are measured with a calibrated dissolved oxygen meter and recorded. All BOD bottles are then incubated in a BOD incubator at 20° C. The dissolved oxygen levels in each bottle can then be read and recorded daily using the membrane electrode method. The bottles are then reaerated employing the technique previously described and the resulting dissolved oxygen levels recorded. This procedure is continued on a daily basis during nitrification screening until the dissolved oxygen depletion levels out. Nitrate- and nitrite-nitrogen levels can then be measured in each BOD bottle as required to determine the degree of nitrification achieved. During carbonaceous screening the bottles can be read daily or simply incubated for a three day period, at which time a final dissolved oxygen measurement in each bottle is determined.

If the wastewater under investigation has an immediate dissolved oxygen demand, this demand should be satisfied prior to adding the wastewater to the BOD bottles. When the wastewater exerts a chemical oxygen demand that occurs slowly, it becomes necessary to set up a duplicate test eliminating the biological culture. The wastewater employed during the duplicate test for determination of chemical oxygen demand should be sterilized to destroy any oxygen consuming microorganisms present in the wastewater to prevent natural seeding.

During the BOD bottle inhibition screening procedure, it is impossible to distinguish between oxygen consumption due to aerobic organotrophic metabolism of the carbon sources in the wastewater (carbonaceous BOD) and oxygen consumption by the aerobic autotrophic microorganisms (nitrification). The oxygen uptake by the nitrifying bacteria in the BOD test has sometimes been termed the "second-stage uptake," and exertion of this oxygen demand is usually not a factor during the five-day incubation period due to low numbers of nitrifying bacteria and their relatively slow growth rates (3). The influence of initial organic carbon concentrations, carbon to nitrogen ratios and growth rates of the carbonaceous microorganisms, as discussed by Stover and Kincannon (4) and Stover, et al. (5), on the rates of nitrification achievable by the nitrifying bacteria become important factors in the design of this experimental approach. These influences on nitrification and the dissolved oxygen consumed by the carbonaceous materials in the wastewater limit this inhibition screening approach to low organic strength wastewaters. The BOD bottles must be aerated daily during the test to minimize anaerobic or anoxic conditions which could allow denitrification of the nitrate- or nitrite-nitrogen produced.

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

RESULTS

Due to concerns for obtaining reliable biological nitrification in a combined municipal-industrial wastewater treatment facility, pilot plant studies, industrial waste surveys and biological inhibition screening studies were conducted to determine the effects of the industrial wastewater discharges on a proposed single-stage activated sludge nitrification treatment facility. Characteristics of the municipal and three industrial wastewaters employed in microbiological nitrification inhibition screening studies are presented in Table 2. These three major industrial contributors to the municipal system account for less than 10 percent of the total wastewater flow and BOD loading into the treatment facilities.

Results from the third day of testing the three industrial wastewaters and the municipal wastewater (control) by the BOD bottle procedure with a mixed culture of carbonaceous and nitrifying activated sludge as seed are shown in Figure 1. The dissolved oxygen depletions do not distinguish between carbonaceous oxidation and nitrification, but this data does indicate no apparent inhibition to biological oxidation in any of the wastewaters as there were no threshold inhibition levels observed. The test was continued for two more days to provide a five-day test condition. Dissolved oxygen depletion remained high in all the BOD bottles with large volumes of wastewaters (low dilutions) indicating no inhibition to biological treatment. At the end of the five-day test period, even though all the oxygen demand had not been satisfied in the low dilution bottles, the test was halted and the contents of selected bottles were analyzed for nitrate-nitrogen production (Table 3). Nitrate-nitrogen production was observed in all the bottles with lowest concentrations appearing in the low dilution (high volume wastewater) bottles in most cases. No apparent threshold inhibition levels to nitrification were observed in these tests with the four wastewaters.

Due to the halting of the test at five days before exertion of most of the oxygen demand in the low dilution bottles and the consequently low nitrate-nitrogen production in some bottles, batch activated sludge nitrification rate investigations were also conducted to verify the conclusions of the BOD bottle test procedure. Environmental conditions, BOD loadings (F/M ratios) and BOD/TKN ratios were monitored and controlled in each reactor to insure comparable test conditions. The nitrification rates observed from these test reactors indicated the same conclusions as the BOD bottle test with no nitrification inhibition occurring from these industrial wastewaters (Figure 2).

Microbiological inhibition screening procedures were also conducted on two samples of sanitary landfill leachate collected during different time periods for assessment of the feasibility of treating the leachate in an existing biological treatment facility. The leachate flow rate was estimated to be around one percent of the average daily flow through the treatment facility, and the results of the characterization of the two samples are presented in Table 4.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-70)

TABLE 2. RAW WASTEWATER CHARACTERISTICS (mg/L EXCEPT pH)

Parameter	Municipal wastewater	Industrial wastewaters		
		No. 1	No. 2	No. 3
COD	450	500	830	510
BOD	135	150	210	210
TKN	20	30	3	200
NH_3-N	10	10	1	150
NO_2-N	0.01	0.4	0.2	0.01
NO_3-N	0.1	0.1	0.3	0.1
TDS	375	1,100	750	930
SS	100	600	100	400
pH	7.0	8.5	7.0	8.0
Percent total flow	93	4	2	1
Percent BOD load	92	4	3	1

TYPING GUIDE SHEET
EPA-287 (Cin.)
(4-76)

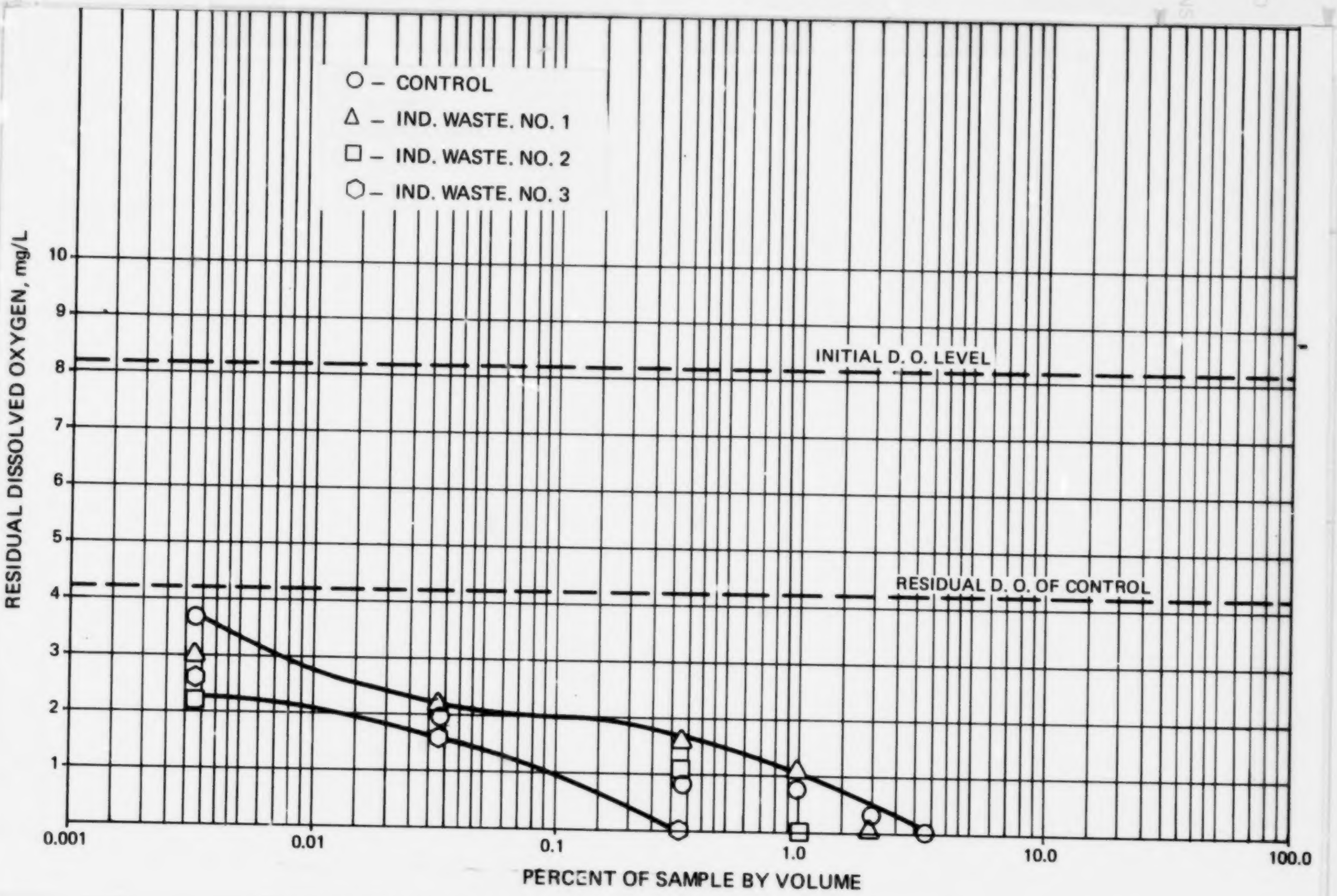


FIGURE 1 RESULTS OF MICROBIOLOGICAL INHIBITION TESTING OF INDUSTRIAL WASTEWATERS (CARBONACEOUS)

TABLE 3. NITRATE-NITROGEN IN BOD BOTTLES AT FIVE DAYS (mg/L)

Bottle No.	Wastewater volume, ml	Municipal wastewater	Industrial wastewaters		
			No. 1	No. 2	No. 3
7	10	1.4	1.2	5.0	0.5
9	60	1.6	2.0	6.9	0.5
10	100	1.4	0.4	4.7	0.5
11	200	0.2	0.5	3.3	0.6

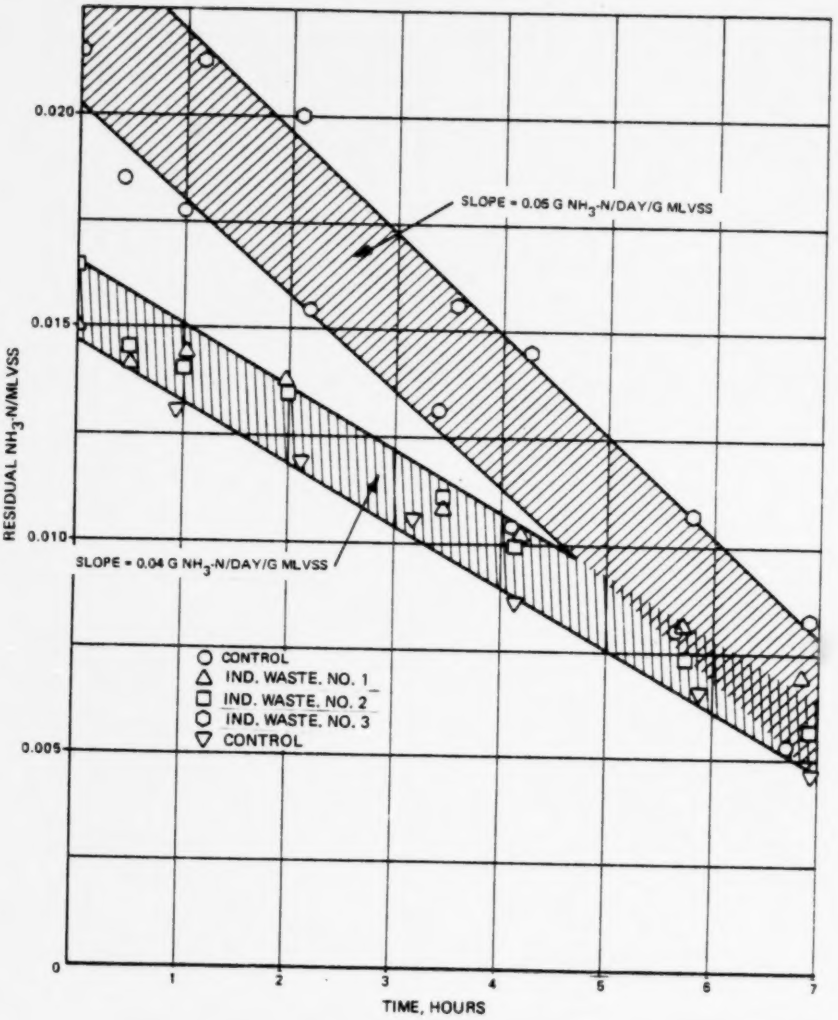


FIGURE 2 NITRIFICATION RATES (G NH_3-N/DAY/G MLVSS) DURING BATCH NITRIFICATION RATE STUDIES

TABLE 4. LANDFILL LEACHATE CHARACTERISTICS
(MG/L EXCEPT PH)

Parameter	Sample No. 1	Sample No. 2
COD	12,000	17,000
BOD	6,600	900
TSS	150	460
VSS	51	230
TDS	9,400	3,200
pH	5.5	3.3

During inhibition testing of the first sample where the BOD was around 50 percent of the COD value, no apparent threshold inhibition level to biological treatment was observed. However, during inhibition screening of the second sample with the low BOD value (around 5 percent of the COD), a threshold inhibition level to biological treatment was observed at about a dilution of one percent of the sample by volume as indicated in Figure 3. At dilutions of leachate wastewater greater than 10 percent by volume, chemical oxidation reactions were observed to consume oxygen and show up as an oxygen demand (Figure 3) as determined by conducting a second set of tests with sterilized wastewater and no biological seed. These test results verified a concern for variable leachate chemical composition and the requirement of physical/chemical pretreatment of the landfill leachate prior to discharge to the biological system.

DISCUSSION AND CONCLUSIONS

The microbiological inhibition screening procedures previously presented can be employed to provide estimates of the threshold inhibition levels for both carbonaceous treatment and nitrification. The nitrification procedure, as presented, is only applicable to low organic strength wastewaters, since ammonia-nitrogen removal by synthesis reactions is the dominating or controlling process over ammonia-nitrogen oxidation. A competing or crowding effect of fast heterotrophic microorganism growth rates at increased changes in influent organic concentrations has been observed to reduce nitrification reactions in both fluidized and fixed bed reactors under conditions of excess ammonia-nitrogen available for oxidation. (4,5,6,7,8) Since the nitrification reactions would initially lag the carbonaceous reactions at the lower dilutions, the BOD bottles must be reaerated and incubated until the carbonaceous oxygen consumption has leveled out. High organic strength wastewaters would require running the test for long periods of time. The BOD bottles must also be maintained under aerobic conditions after the nitrification reactions have started to prevent denitrification of the nitrate-nitrogen produced. The experimental design and interpretation of results from the nitrification screening procedure must be conducted by an

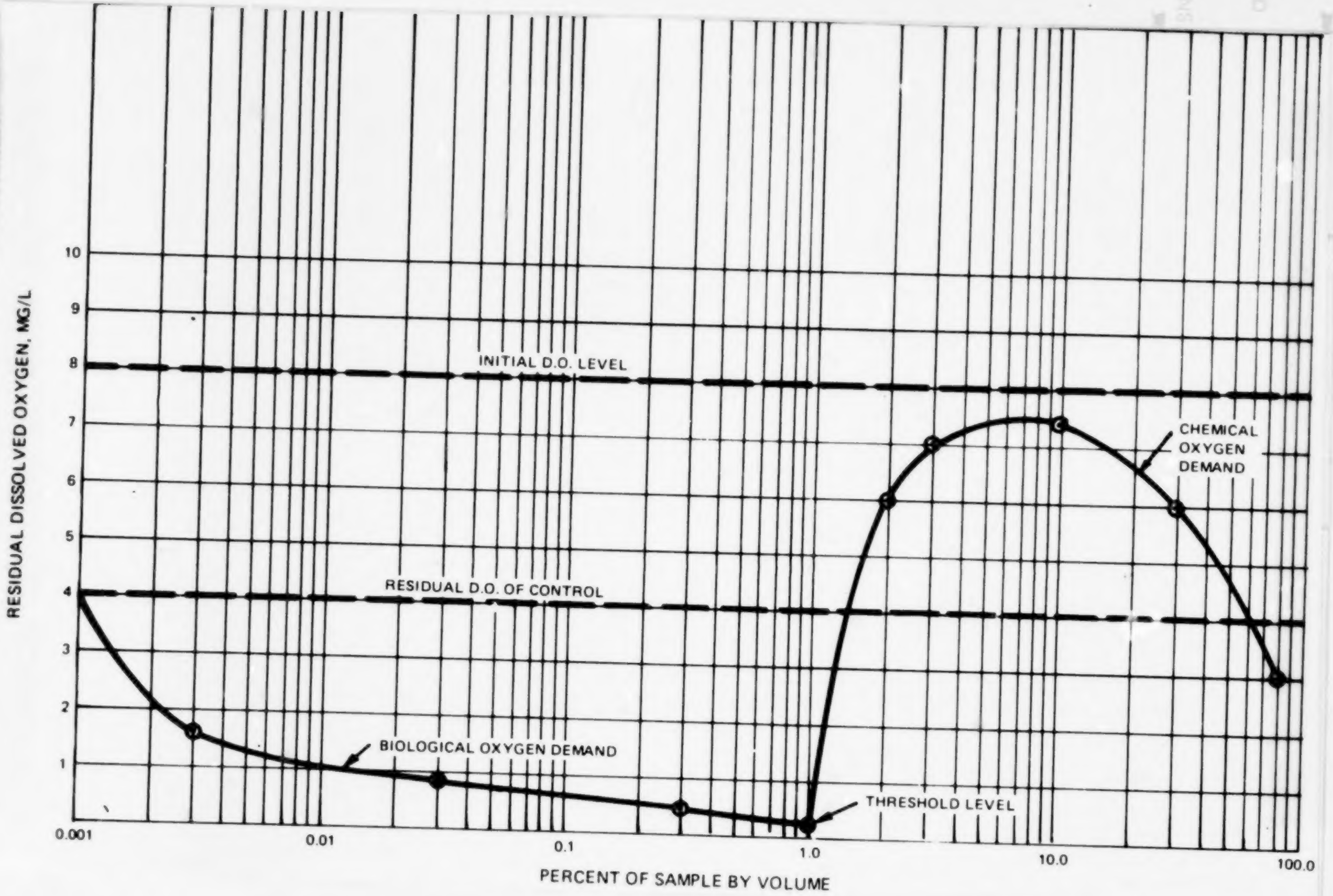


FIGURE 3 RESULTS OF CARBONACEOUS MICROBIOLOGICAL INHIBITION TESTING OF SANITARY LANDFILL LEACHATE

individual with a thorough understanding of the nitrification process and its influencing factors.

This nitrification inhibition screening procedure could be simplified by the use of pure cultures of nitrifying bacteria (*Nitrosomonas* or *Nitrobacter*) for biological seed and addition of ammonia-nitrogen or nitrate-nitrogen as required by the wastewater characteristics under investigation. By sterilization of the wastewater and addition of pure cultures of nitrifying bacteria to the BOD bottles, the oxygen consumption measured could be distinguished as nitrification, and the test procedure could be simplified to the same format as that for carbonaceous inhibition screening.

Freeze-dried *Nitrobacter* has been employed as the test organism for bioassay testing of toxicity in municipal and industrial wastewaters by monitoring nitrite-nitrogen removal or nitrate-nitrogen production (9). Freeze-dried bacterial cells eliminate the need for developing and maintaining an active bacterial culture and provide a means of preserving the microorganisms over long time periods for storage and shipping. By using freeze-dried *Nitrosomonas* as the test organism in the BOD bottle, the first stage of ammonia-nitrogen oxidation could easily be monitored for inhibition by simply monitoring oxygen uptake.

EPA-287 (Cin.)
(4-76)

REFERENCES

1. Marks, P. J., "Microbiological Inhibition Testing Procedure." Presented at the Symposium of Environmental Monitoring ASTM Annual Meeting (1972).

2. Standard Methods for the Examination of Water and Wastewater, 14th ed., American Public Health Association, New York (1975).

3. Gaudy, A. F., Jr., "Biochemical Oxygen Demand." In Water Pollution Microbiology, John Wiley & Sons (1972).

4. Stover, E. L. and Kincannon, D. F., "Effects of COD: NH3-N Ratio on a One-Stage Nitrification Activated Sludge System." Water and Sewage Works, 123, 9, 120 (1976).

5. Stover, E. L., et al., "Inhibiting Nitrification in Wastewater Treatment Plants." Water and Sewage Works, 123, 8, 56 (1976).

6. Stover, E. L. and Kincannon, D. F., "One-step Nitrification and Carbon Removal." Water and Sewage Works, 122, 6, 66, (1975).

7. Saidi, H., "Studies on the Hydrolytically-Assisted Extended Aeration Process and on Pre-Hydrolysis of Sludge in Aerobic Digestion Processes." Master's Thesis, Oklahoma State University, Stillwater, Oklahoma (1974).

8. Murthy, K. S. N., "Operational Performance and Nitrifying Characteristics of a Hydrolytically-Assisted Extended Aeration Process at High Organic Loadings." Master's Thesis, Oklahoma State University, Stillwater, Oklahoma (1974).

9. Williamson, K. J. and Johnson, D. G., "A Bacterial Bioassay for Assessment of Wastewater Toxicity." Presented at the 34th Purdue Industrial Waste Conference, West Lafayette, Indiana (May, 1979).

PB83-142208

TREATMENT OF MUNICIPAL WASTEWATERS CONTAINING BIOLOGICALLY HAZARDOUS INDUSTRIAL COMPOUNDS BY CONVENTIONAL ACTIVATED SLUDGE AND EXTENDED AERATION

by

D. F. Kincannon
Oklahoma State University
School of Civil Engineering
Stillwater, Oklahoma 74078

A. F. Gaudy, Jr.
University of Delaware
Department of Civil Engineering
Newark, Delaware 19711

T. S. Manickam
Oklahoma State University
School of Civil Engineering
Stillwater, Oklahoma 74078

ABSTRACT

Internal recycle bench scale reactors were used to study the effects of phenol, 2-chlorophenol, methylene chloride, and 4-chloro,3-methyl phenol on activated sludge and extended aeration processes treating a municipal wastewater. The activated sludge process was operated at a mean cell residence time of five days. The only solids wasted in the extended aeration units were those used for analyses and whatever solids were in the effluent from the final clarifier. The results of this study showed that the effluents of the extended aeration pilot plants were lower in soluble COD and particularly in suspended solids concentration than effluents from the 5-day θ_c systems. Increased suspended solids due to the presence of priority pollutants led to operational problems in maintaining a steady mean cell residence time except in the case of 4-chloro,3-methyl phenol. Presence of 4-chloro,3-methyl phenol did not upset the steady mean cell residence time. There was no evidence for massive pass through of any of the compounds for which specific analytical determination was made even at the high dosage level of 50 mg/l.

INTRODUCTION

Wastewater treatment plants that are being constructed today are expected to provide adequate, uninterrupted, stable removal of the influent organic components of the waste. Many sewers from various manufacturing plants tie into the municipal sewer. Many industrial wastes, particularly those from the chemical manufacturing industries, contain a variety of compounds which may or may not be substrates for the heterogeneous microbial populations of which activated sludge is composed. It is vital, therefore, to have reliable data for determining the limits of compatibility and/or the required pretreatment level for acceptance of questionable compounds into municipal plants. The concentration effect of many organic compounds on natural biomasses in municipal treatment plants is generally not known. Some waste components may be toxic, while some may enhance the biological activity and vitality of the sludge. On the other hand, some wastes may cause upsets at the plant for a time and some may permanently cause a decrease in treatment efficiency. The decreased efficiency may be in the form of greater leakage of soluble organic matter or it may be due to interference with the floccing and settling tendencies of the sludge in the secondary clarifier.

Barth and Bunch (1) have reported on the biodegradability and treatability of various organic pollutants. Microbial cells were acclimated to 300 mg/l of phenol and then fed 100 mg/l of the test compound. Biodegradability was measured by comparing oxygen uptake rates. They found that the biodegradability of a test compound could vary depending upon acclimation. Tabak and Barth (2) studied the biodegradation of benzidine with acclimated extended aeration sludges. They found that complete oxidation of benzidine occurs at benzidine concentrations of 1 mg/l. At higher concentrations less complete oxidation occurred, however, no marked interference with carbonaceous removal efficiency was noted.

Murray Strier (3), in an EPA internal report, has done an excellent job in evaluating the treatability of 65 various organic chemicals. He has also developed a procedure for predicting the biodegradation of organic chemicals.

The study reported on in this paper not only looked at the fate of the organic compound but also its effect on the treatment process treating a municipal wastewater

MATERIALS AND METHODS

Internal recycle continuous flow bench scale reactors were used for conducting this study. The activated sludge units were operated at a hydraulic retention time of 8 hours and an observed growth rate of 0.2 days^{-1} (θ_c = 5 days). The growth rate was maintained by proportional wasting of mixed liquor after removing the baffle separating the aeration and settling chambers. The extended aeration systems were operated at a hydraulic retention time of 15.7 hours and no sludge other than that used for sampling and the carry over from the clarifier was wasted.

The normal feed stock consisted of effluent from the primary clarifier of the Stillwater municipal sewage treatment plant. A large supply of sewage was obtained daily for this purpose. The BOD_5 of the sewage was very low, therefore, the sewage was supplemented with 200 mg/l glucose and 75 mg/l ammonium sulfate. To this base feedstock, various concentrations of the test compound were added as desired during the conduct of the experimentation. Concentrations used were 5, 20 or 25, and 50 mg/l.

The major analytical technique employed was Chemical Oxygen Demand (COD), as a measure of total and soluble organic matter in the influent and effluent. Mixed liquor suspended solids and effluent suspended solids were measured with a membrane filter (0.45μ pore size). These analyses were run in accordance with "Standard Methods for the Examination of Water and Wastewater"(4).

Dissolved oxygen, pH, and temperature were measured periodically in the reactors. Analyses were performed using a F and M Research Chromatograph (Model 810) for the presence of the test compounds in the feed, mixed liquor, and effluent.

RESULTS

Four compounds (phenol, 2-chlorophenol, methylene chloride, and 4-chloro, 2-methyl phenol) were chosen for study in continuous flow pilot plants operated at $\mu_n = 0.2\ \text{day}^{-1}$ and also in extended aeration plants.

Phenol

Figure 1 shows the performance of an activated sludge unit operating at a sludge age (θ_c) of 5 days before and after receiving phenol dosages of 5, 20, and 50 mg/l. The actual sludge age achieved in the unit gives a good indication of the operational stability. Before phenol was introduced to the unit a very stable θ_c value was obtained. After 5 mg/l phenol was introduced to the reactor, the sludge age varied a great deal and then became more stable. However, when the phenol concentration was increased to 20 mg/l, the sludge age again became unstable. With a phenol concentration of 50 mg/l, the sludge age not only continued to be unstable but also decreased to a very low level. It is also seen that the mixed liquor solids showed a gradual decrease throughout the study. Effluent COD and suspended solids increased sufficiently with the 50 mg/l loading and during the cyclic changes. Table 1 gives a statistical summary of the data. The filtrate COD increased from an average value of 30.3 mg/l before the phenol loading to 99.0 mg/l during the cyclic changes.

The general impression received when one compares results shown in Figure 2 for an extended aeration plant receiving varying dosages of phenol with results for actived sludge at $\theta_c = 5$ days is that the extended aeration pilot plant gave somewhat better results with respect to suspended solids concentration in the effluent. However, it is clear that the presence of phenol did cause some deterioration in effluent quality. It can be seen that the addition of even 5 mg/l phenol in the feed caused an increase in soluble COD and a rise in suspended solids in the effluent. However, after the unit had acclimated to this concentration of phenol, an increase from 5 to 20 mg/l did not appear to affect the concentration of soluble COD in the effluent although there was a short-lived rising trend in the effluent suspended solids concentration. An increase to 50 mg/l caused a rising tendency in soluble COD and some increase in effluent suspended solids concentration.

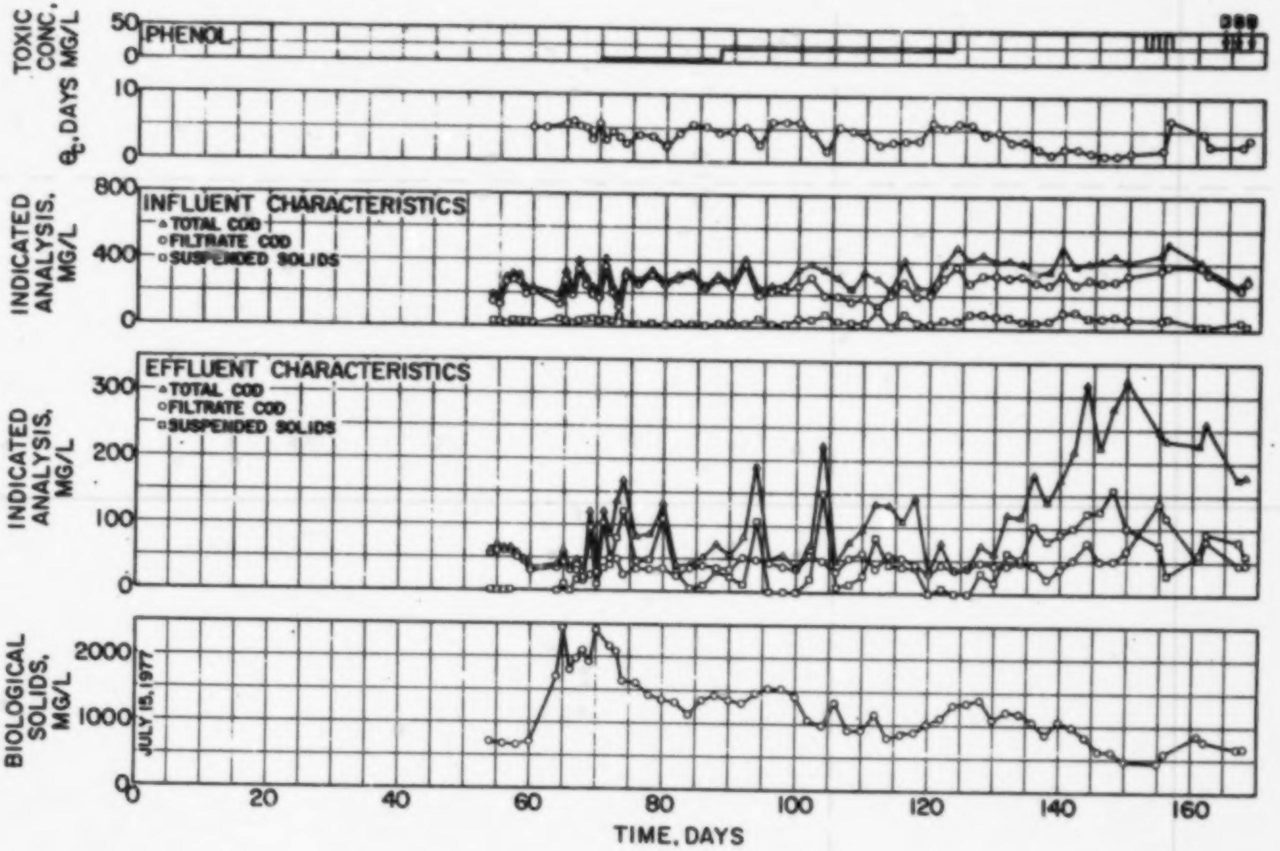


Figure 1. Response of activated sludge system to phenol. θ_c = 5 days.

TABLE 1. STATISTICAL OPERATIONAL DATA FOR STUDY UNITS

Priority Pollutant	Para-meters	θ_c = 5 Days				Extended Aeration				Remarks
			Effluent COD				Effluent COD			
		MLSS	Total	Fil	S.S	MLSS	Total	Fil	S.S	
Phenol	N	7	7	7	7	25	21	21	25	No priority pollutant added
	X	2053.6	54.3	30.3	21.6	1371.4	48.2	23.8	36.7	
	N	11	11	11	11	33	31	31	33	5 mg/1 priority pollutant added
	X	1650.5	92.5	42.2	59.3	1734.2	62.0	45.9	29.8	
	N	17	17	17	17	16	16	16	16	20 mg/1 priority pollutant added
	X	1154.7	92.2	45.2	33.8	1545.6	54.7	41.1	25.6	
	N	14	14	14	14	5	4	5	5	50 mg/1 priority pollutant added
	X	1002.1	164.6	47.0	74.6	2329.2	86.5	64.2	58.8	
	N	4	4	4	4	13	1	10	13	Cyclic changes
	X	675.8	242.0	99.0	64.8	2422.8	281.0	78.2	66.1	
2 Chloro Phenol	N	10	10	10	10	9	9	9	9	No toxic compound added
	X	1275.8	137.2	61.2	51.7	2414.0	61.1	47.0	53.9	
	N	13	13	13	13	11	9	9	11	5 mg/1 priority pollutant added
	X	1171.3	148.7	52.8	65.1	2010.9	65.1	55.1	16.8	
	N	15	15	15	15	16	16	16	16	25 mg/1 priority pollutant added
	X	1253.5	96.4	39.7	50.3	1550.0	48.2	33.1	32.8	
	N	21	21	21	21	21	21	21	21	50 mg/1 priority pollutant added
	X	1209.7	147.7	50.0	80.8	1374.7	60.0	46.8	36.4	
	N	44	44	44	44	40	40	40	40	Cyclic changes
	X	1036.7	118.5	42.6	69.3	1526.0	42.6	35.6	13.8	

TYPING GUIDE SHEET
EPA-287 (Cin.) (4-78)

TABLE 1. (continued)

Priority Pollutant	Para-meters	θ_c = 5 Days				Extended Aeration				
			Effluent COD				Effluent COD			
		MLSS	Total	Fil	S.S	MLSS	Total	Fil	S.S	
Methylene Chloride	N	3	3	3	3	16	16	16	16	No priority pollutant added
	X	818.3	198.0	48.0	109.3	2008.8	45.1	34.9	25.8	
	N	19	19	19	19	16	16	16	16	5 mg/1 priority pollutant added
	X	749.0	162.1	47.0	85.4	1950.0	33.7	21.6	18.4	
	N	21	21	21	20	23	23	23	23	25 mg/1 priority pollutant added
	X	872.2	142.8	37.1	96.7	2204.3	39.1	27.9	18.5	
	N	14	14	14	14	14	13	13	13	50 mg/1 priority pollutant added
	X	615.4	188.5	51.4	108.6	1812.1	38.3	22.1	20.9	
	N	17	18	18	18	17	15	16	19	Cyclic changes
	X	824.4	170.8	57.4	93.1	3287.6	34.5	32.1	3.7	
4 Chloro 3 Methyl Phenol	N	6	5	6	5	6	5	6	6	No priority pollutant added
	X	1635.8	93.0	75.3	23.4	4816.2	45.0	42.0	3.8	
	N	17	17	17	18	18	18	13	18	5 mg/1 priority pollutant added
	X	1848.7	62.3	55.2	7.6	4843.6	31.0	31.5	4.9	
	N	10	10	10	10	10	10	9	9	25 mg/1 priority pollutant added
	X	1780.6	57.9	46.2	6.0	5618.4	31.6	30.6	3.4	
	N	12	12	12	12	13	9	9	12	50 mg/1 priority pollutant added
	X	1549.9	88.4	56.8	26.9	6407.0	60.1	58.8	3.9	

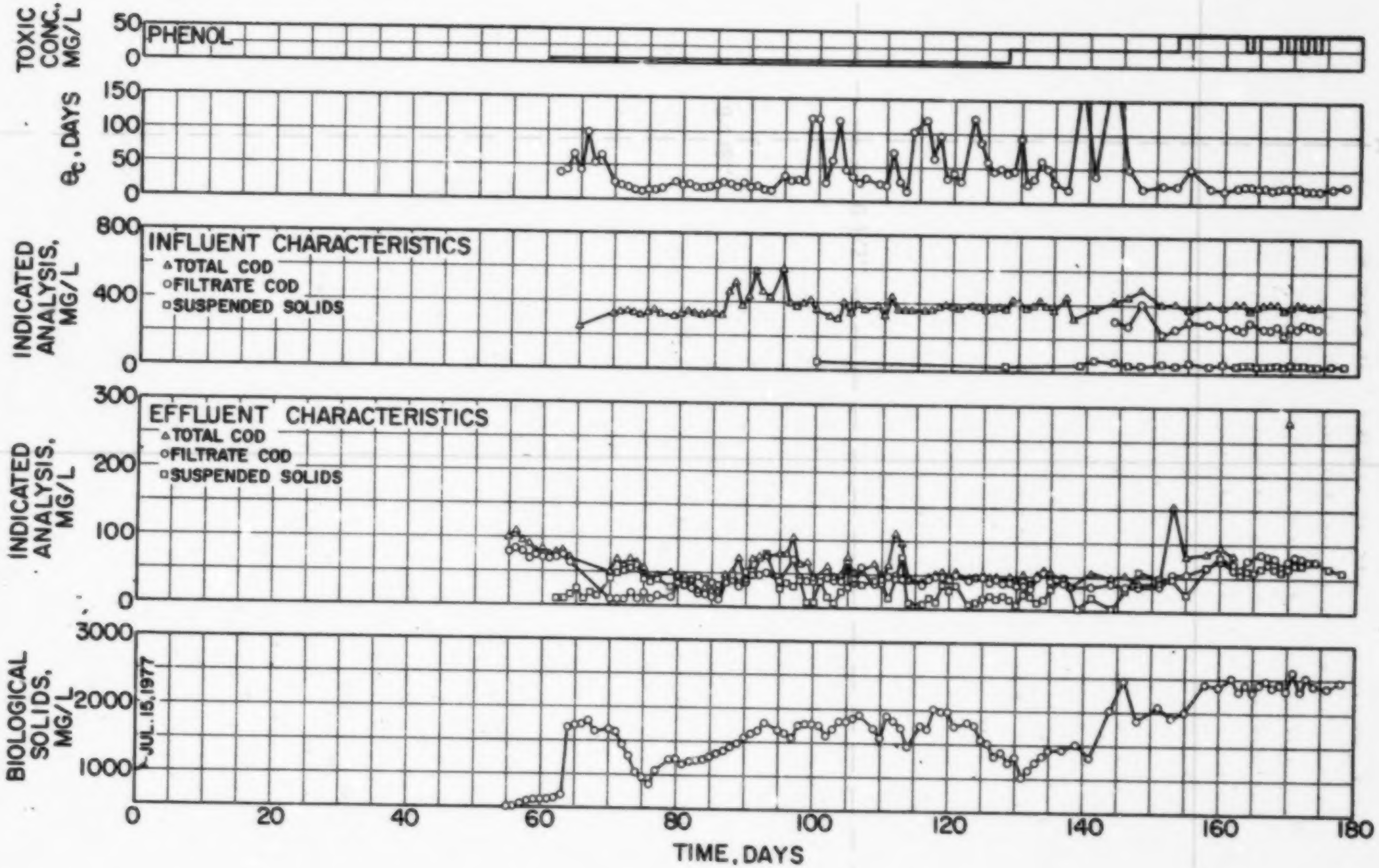


Figure 2. Response of activated sludge system to phenol. Extended aeration.

When the unit was subjected to shock loadings at the end of the experimental period, the effluent COD did not increase to the extent experienced for the faster growing sludge of Figure 1.

Statistical analysis on the operational data obtained from the extended aeration process during the various periods of loadings is shown in Table 1. It is seen that, on average, all dosages caused a somewhat higher total effluent COD than was observed for the faster growing sludge in the control unit. In general, it can be seen by comparing Figures 1 and 2 and the statistical analyses (Table 1) that the extended aeration unit was subject to a lesser amount of deterioration in effluent quality than was the faster growing activated sludge. Microscopic examinations made during the experimental period indicated there were rather large amounts of filamentous growth in the extended aeration sludge as well as in the faster growing sludge. The onset of filamentous growth in both units corresponded with the beginning of phenol dosage and the filamentous growth continued to increase as phenol dosage was increased. However, it increased at a significantly slower rate in the extended aeration sludge than in the faster growing biomass.

2-Chlorophenol

Figure 3 shows the response of the continuous flow unit to varying dosages of 2-chlorophenol.

After a short acclimation period the system could accommodate rather well to the 5 mg/l level of 2-chlorophenol. However, the suspended solids concentration in the effluent was rather high. It became progressively worse as the dosage was increased. It seems from these results that one may expect that 2-chlorophenol will lead to higher effluent suspended solids concentrations which, in turn, make it difficult to operate the system at a steady mean cell residence time as evident in Figure 3. This was more apparent at a concentration of 25 mg/l and above.

Figure 4 shows the performance of the extended aeration activated sludge pilot plant receiving dosages of 2-chlorophenol. This activated sludge pilot plant had previously been receiving phenol as a test compound. However, the system had not been fed the previous test compound for at least 15 days prior the initiation of data taking.

During the early stages there was a falling trend in the biomass concentrations. The suspended solids concentration in the effluent was rather low. In general, during this period, the effluent from the extended aeration unit was considerably better than that for the 5 day θ_c activated sludge which received similar dosage of the test compound. Shortly after increasing the dosage to 50 mg/l, there was a noticable change in predominant species and in appearance of the sludge. There was a decrease in protozoan population and a concomitant increase in effluent suspended solids concentration which resulted in a wide fluctuation in the mean cell residence time. However, within three weeks the effluent solids concentration returned to its normally low level and remained so during the pulsating loading period. Throughout the remainder of the experimentation, the protozoan population increased but was

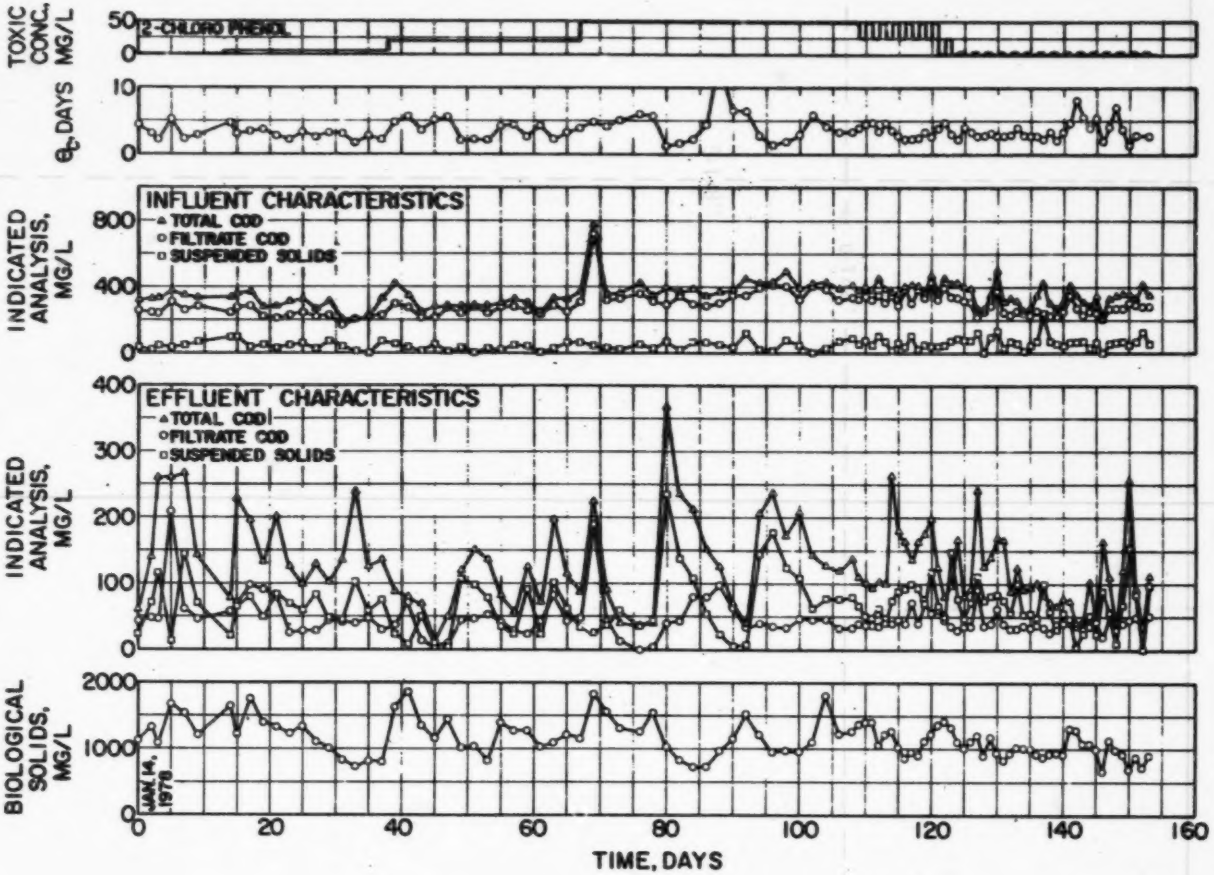


Figure 3. Response of activated sludge system to 2-chlorophenol. θ_c = 5 days.

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
DROPPED HEAD; BEGIN SECTIONS HERE
CENTER OF PAGE
TOP OF IMAGE AREA
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER
EPA-287 (Cin.)

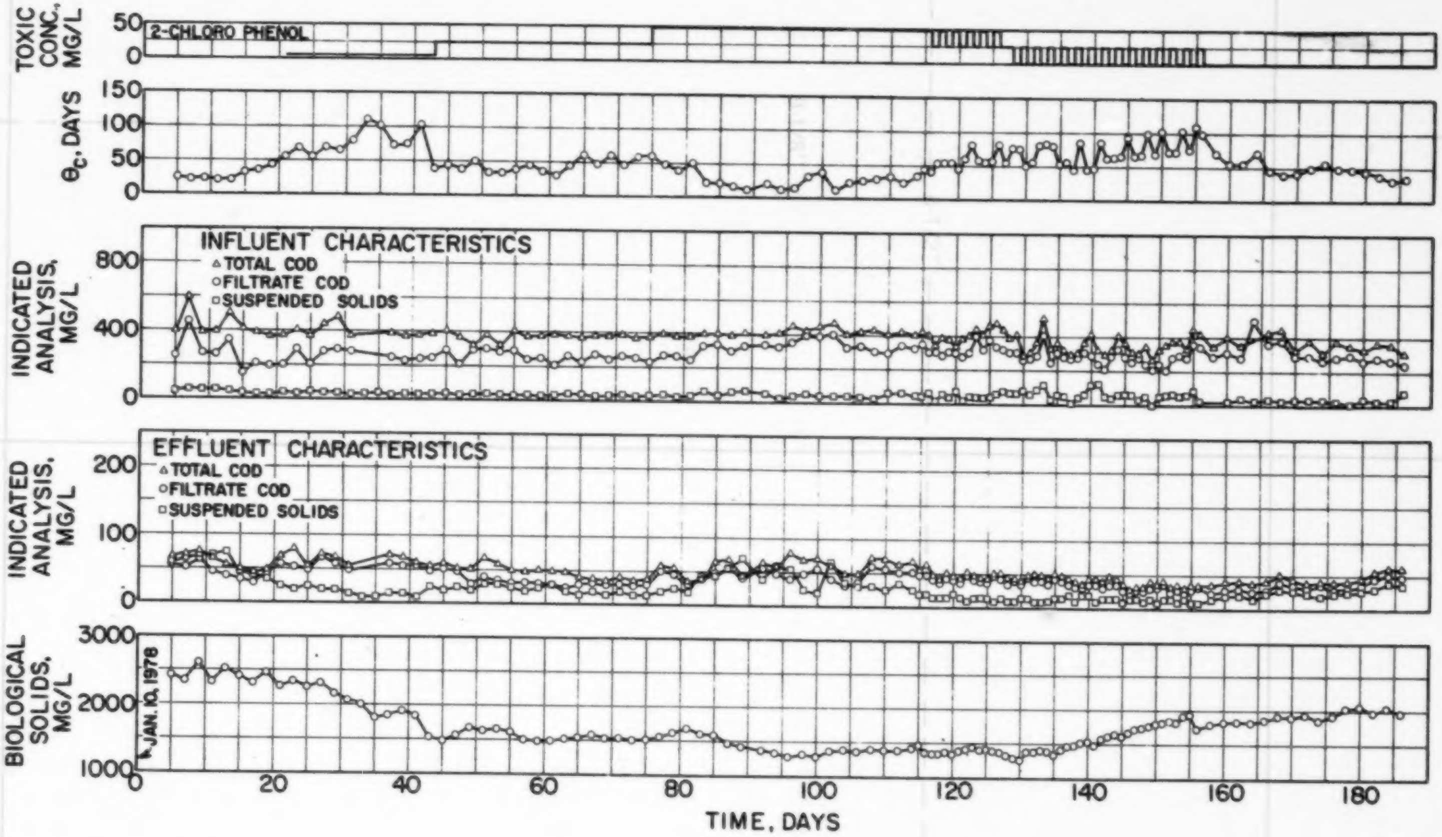


Figure 4. Response of activated sludge system to 2-chlorophenol. Extended aeration.

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
DROPPED HEAD, BEGIN SECTIONS HERE
CENTER OF PAGE
TOP OF IMAGE AREA
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
BEGIN LAST LINE OF TEXT
3/8"
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

not totally restored to the high level of activity observed before increasing the concentration to 50 mg/l in the feed.

Methylene Chloride

Results for the pilot plant which received varying dosages of methylene chloride are shown in Figure 5. Statistical analyses for this unit showed that prior to introducing the test compound the unit exhibited rather high effluent suspended solids. Cyclical dosing with methylene chloride did not appear to cause the system any more stress than steady dosing at 50 mg/l nor did the resting periods appear to help the system recover. The only noticeable effect during cycling between 25 → 0 → 25 mg/l was the increase in mixed liquor suspended solids. Much further study would be required in order to provide a more scientifically satisfactory and informative assessment of the effect of cyclical loading of this compound compared to a "steady diet" of the compound.

The performance of the continuous flow unit which was operated as an extended aeration activated sludge system is shown in Figure 6. Comparison of the results shown in this figure for the extended aeration system with those of Figure 5 for the faster growing system demonstrate, quite strikingly, the better overall effluent quality of the extended aeration system and the fact that the better quality effluent was due to its lower suspended solids concentrations.

Periodic microscopic examinations of both sludges indicated that the extended aeration sludge was much more flocculant and contained fewer filaments and a greater number of protozoa than the faster growing sludge. During the period when the load was pulsed 50 → 25 → 50 mg/l or 25 → 0 → 25 mg/l, there was a slight increase in soluble COD in the effluent but little or no change in effluent suspended solids concentration. There was a rather significant increase in mixed liquor suspended solids during the period of pulsating loading. The same general effect on mixed liquor suspended solids was observed in the faster growing system (see Figure 5). This effect, if sustained, could be important, particularly in the case of extended aeration, since success of such a process is militated against by build-up of mixed liquor suspended solids.

4-Chloro,3-Methyl Phenol

The response of an activated sludge pilot plant to varying dosages of 4-chloro,3-methyl phenol is shown in Figure 7. It is seen that the performance of the test unit was excellent. When the dosage was changed from 5 to 25 mg/l there was a short-lived increase in filtrate COD. However, the system rapidly recovered. There was considerably greater upset when the dosage was increased from 25 to 50 mg/l. The COD leakage was associated primarily with leakage of soluble COD in the effluent rather than COD due to effluent suspended solids. However, it is clear from the experimental data that the addition of this test compound at the concentrations studied herein can cause temporary, if not long-lived, disturbance of effluent quality. Unlike other priority pollutants studied herein, the presence of 4-chloro,3-methyl phenol

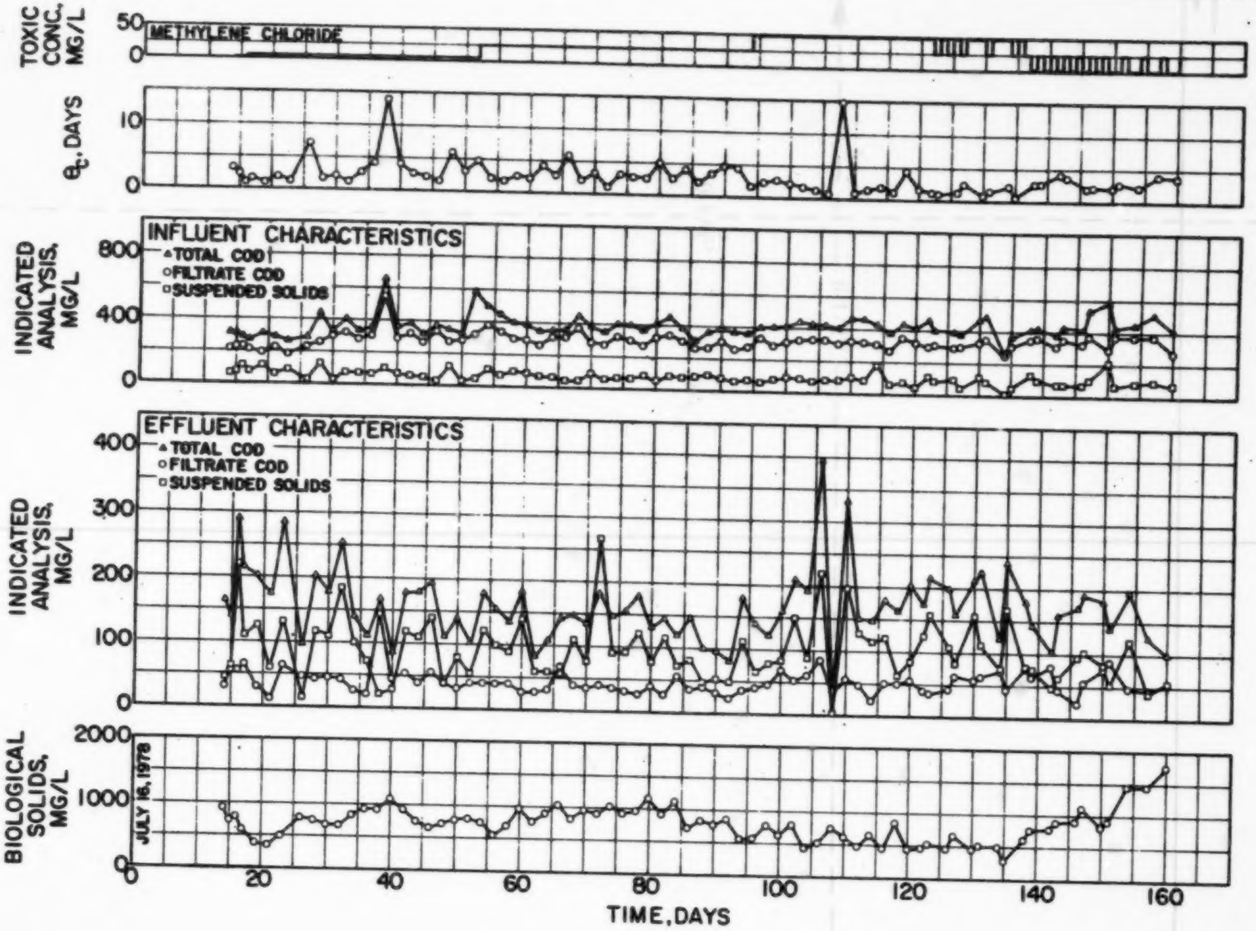


Figure 5. Response of activated sludge system to methylene chloride. θ_c = 5 days.

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

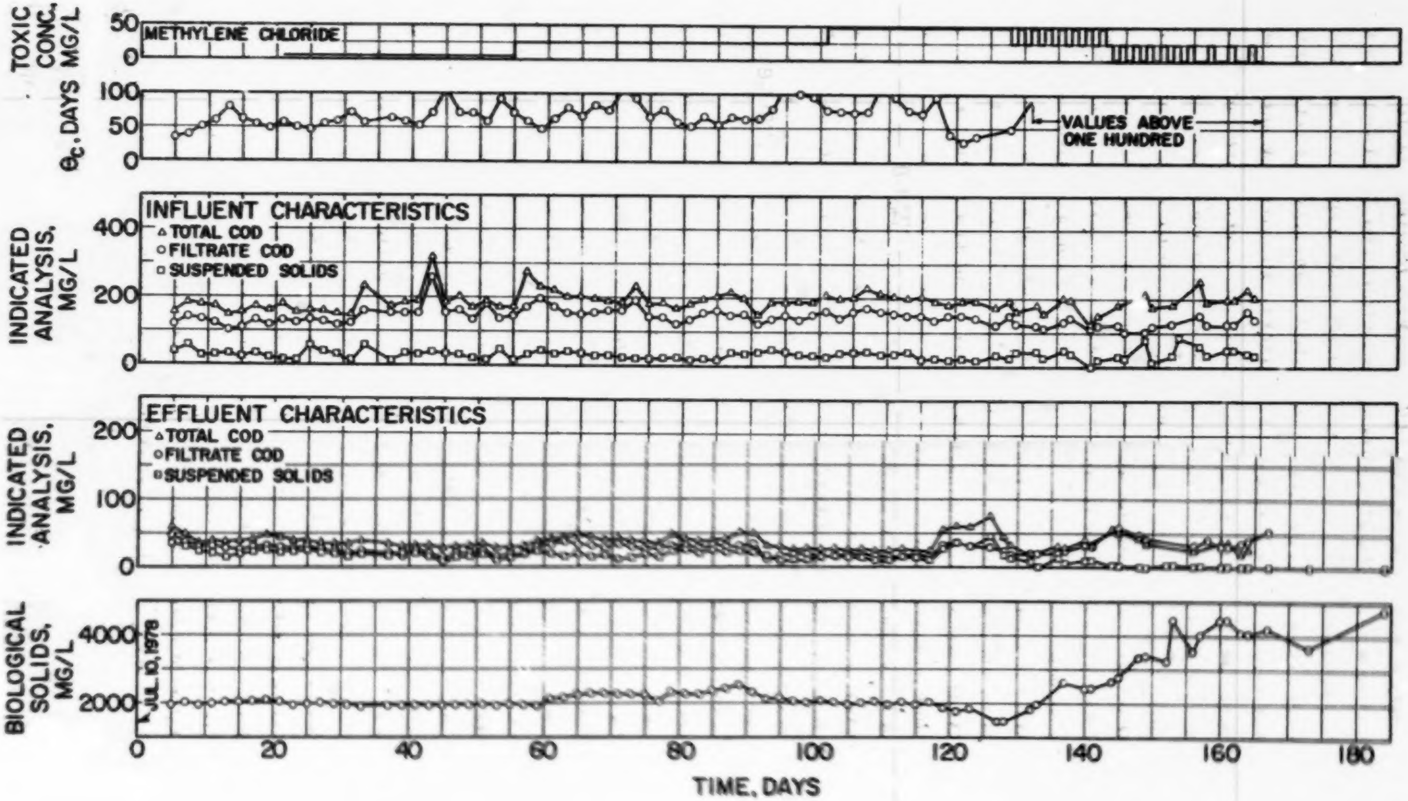


Figure 6. Response of activated sludge system to methylene chloride. Extended aeration.

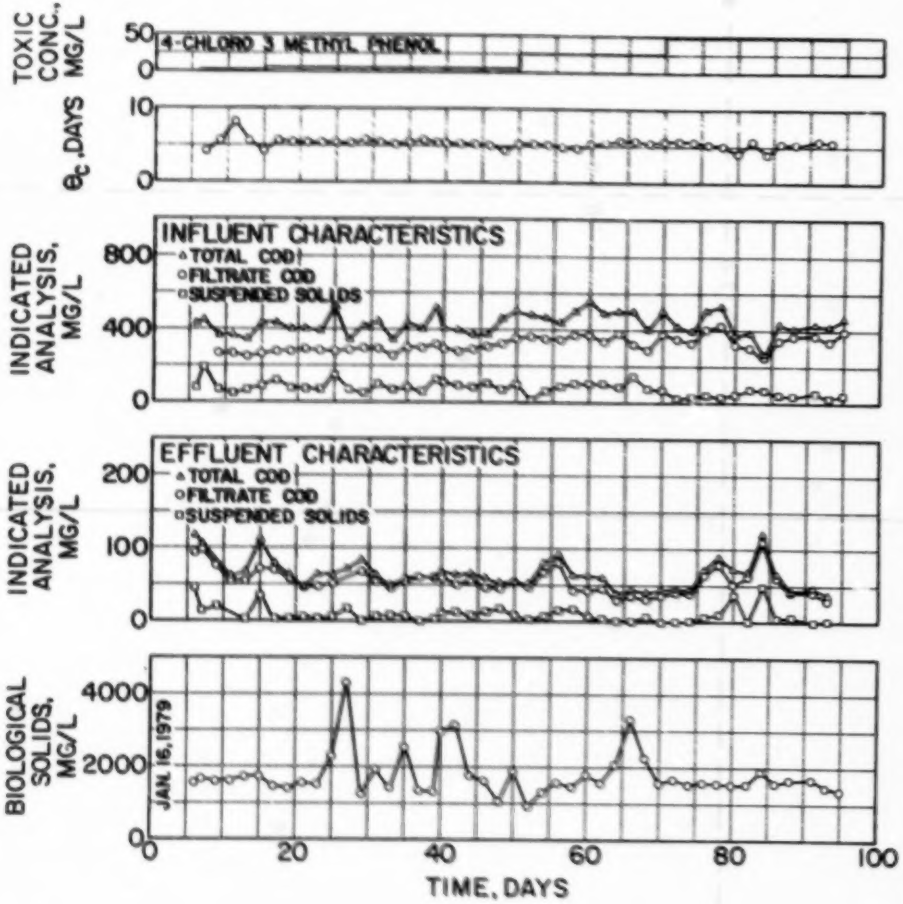


Figure 7. Response of activated sludge system to 4-chloro, 3-methyl phenol. $\theta_c = 5$ days.

did not cause any operational problems in maintaining a steady mean cell residence time of about 5 days.

The performance of an extended aeration process dosed with varying concentrations of 4-chloro,3-methyl phenol is shown in Figure 8 and statistical analyses of these data are presented in Table 1. It is clear from comparison of Figure 8 with the performance of the faster growing system (see Figure 7) that at 5 and 25 mg/l dosage of the test compound the extended aeration system provided much better effluent. The COD in the effluent increased during the 50 mg/l dosage level. The increase was due primarily to an increase in soluble COD. Since the same tendency was noted in the control system during this period of operation, it is difficult to say whether the increase in soluble COD in the extended aeration pilot plant effluent was due to the increased dosage of the test compound or was a natural consequence of some unknown constituent introduced with the municipal sewage. In any event, it is clear that prior to the occurrence the extended aeration process showed a much greater ability to handle the test compound at significantly high dosage levels, i.e., 5 and 25 mg/l.

Concentrations of Pollutants

Table 2 gives a summary for the quantitative analysis of the four pollutants studied. It is seen that fairly good recovery was achieved in the feed. It can also be seen that very low concentrations of the pollutants were found in the mixed liquor and effluent except during the 25 ⟶ 50 cycle for 2-chlorophenol. A concentration of 31.0 mg/l was found in the effluent during this period.

CONCLUSIONS

Based on the results of pilot plant studies and upon observations during the two-year experimental period, as well as results of auxiliary studies made as the work progressed, the following conclusions with respect to the 4 priority pollutants seem warranted.

1. a. For the 4 compounds tested in the continuous flow activated sludge pilot plants operated at $\theta_c = 5$ days ($\mu_n = 0.2$ days^{-1}) there was no evidence for increased soluble COD in the effluent at the 5 mg/l dosage. At this lower dosage, there was evidence for increased suspended solids in the effluent of pilot plants dosed with phenol and methylene chloride. At the higher dosage levels, there was evidence for an increase in both soluble COD and suspended solids in the effluent for the pilot plant dosed with phenol. For the units dosed with 2-chlorophenol and methylene chloride, soluble COD in the effluent was not affected but there was some disturbance in effluent suspended solids concentration. For the pilot plant dosed with 2-chlorophenol and methylene chloride, cyclic loading led to increased suspended solids in the effluent compared to control.

   b. For the same 4 compounds tested in the extended aeration pilot plant, there was evidence for increased soluble COD in the effluent only

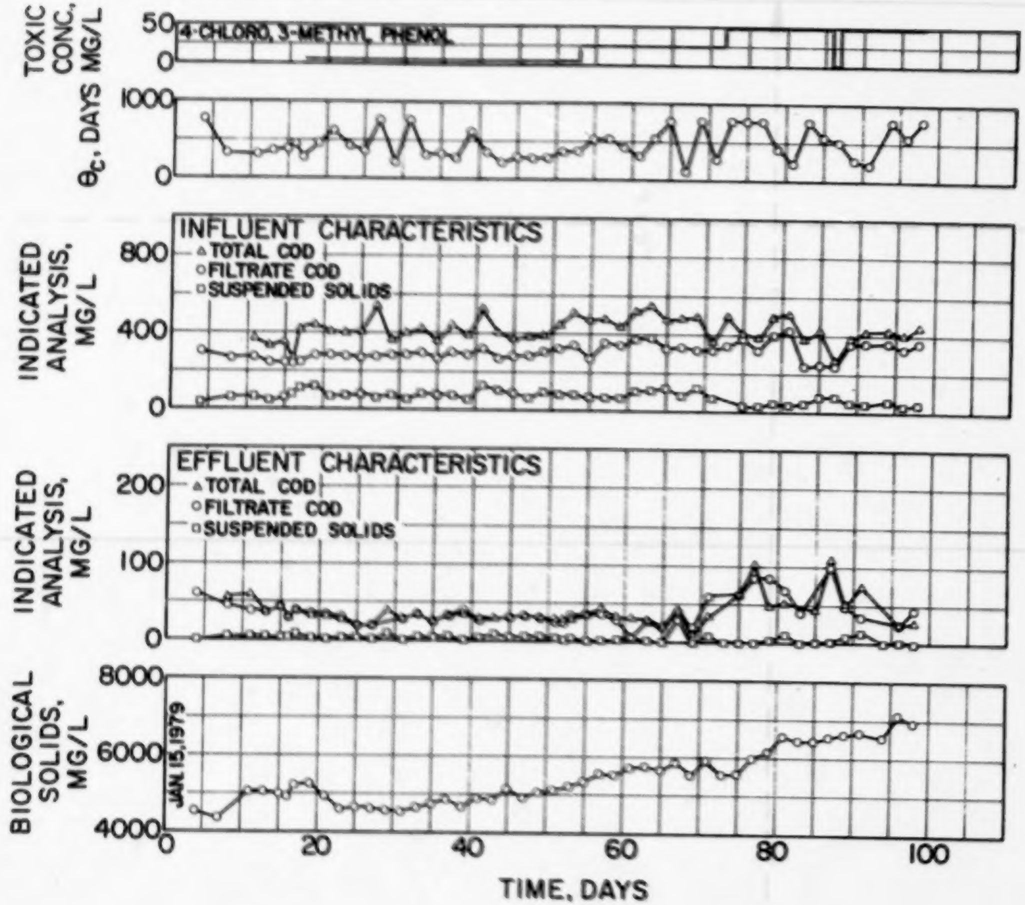


Figure 8. Response of activated sludge system to 4-chloro,3-methyl phenol. Extended aeration.

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
DROPPED HEAD BEGIN SECTIONS HERE
CENTER OF PAGE
TOP OF IMAGE AREA

TABLE 2. RESULTS OF QUANTITATIVE ANALYSIS FOR REMOVAL OF TEST COMPOUNDS. (AVERAGE VALUES)

Name of Compound	Dosage Level mg/1	Concentration of compound Present in the Unit (θ_c=5 days)			Concentration of compound present in the extended aeration system		
		Feed	Mixed Liquor	Settled Effluent	Feed	Mixed Liquor	Settled Effluent
Phenol	20	--	--	0.01	18.1	--	0.007
	50	39.0	0	0.005	--	--	--
	25-50 cycle	--	--	0	--	--	0
2-chlorophenol	5	2.4	<0.001	<0.01	3.0	--	--
	20	12.4	0.02	0.012	--	--	--
	50	32.4	--	--	--	--	<0.0032
	0-25 cycle	--	--	--	--	<0.0064	<0.0032
	25-50 cycle	37.8 (50)	--	31.0	--	--	--
Methylene chloride	5	1.8	<0.001	0.4	--	--	--
	25	--	<0.001	<0.026	--	--	--
	50	--	<0.036	<0.055	--	--	--
	0-25 cycle	--	--	--	8.5	--	<0.001
	0-0-25 cycle	--	--	<0.008	--	--	<0.001
4-Chloro-3 Methyl Phenol	5	--	--	--	6.1	--	<1.6
	25	25.5	<0.08	<0.08	--	--	<1.05
	50	53.3	<0.08	1.1	--	--	<0.08

BEGIN LAST LINE OF TEXT
3/8"
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

from the unit dosed with phenol at the 5 mg/l dosage level. There was no increase in effluent suspended solids in any of the four systems at this dosage level. At the higher levels of dosage (20-25 and 50 mg/l) there was evidence for increased soluble COD and suspended solids only in the units dosed with phenol. Also, only in the unit dosed with phenol was there evidence for disturbance of effluent quality when dosage was changed on alternate days.

Based on the analyses made there was no evidence for massive pass through of any of the compounds for which specific analytical determination was made even at the high dosage level of 50 mg/l. However, small quantities of some of the compounds were detected in the effluents.

2. From the results of this study there was evidence that the effluents of the extended aeration pilot plants were lower in soluble COD and particularly in suspended solids concentration than effluents from comparable faster growing systems. Among reasons for such results may be the lower mass loading rate, i.e., higher biomass concentration and longer mean hydraulic retention time. The reason for the lower suspended solids concentration is probably due to generally greater abundance of protozoa in this sludge as compared to the more rapidly growing system. Generally in the faster growing systems, an increase in dosage of the test compound appeared to cause more serious reduction in protozoan activity than in the extended aeration system. Thus, while the biomass with fewer grazing species could provide nearly equal efficiency with respect to residual soluble COD, it was not possible with respect to suspended solids concentration in the effluent. Therefore, it must be concluded that in designing study procedures to assess effects of priority pollutants on activated sludges, the ecological considerations as reflected in effluent clarity as well as other aspects of ecology, such as limiting effects on species diversity, should be included as parameters for assessment.

3. Increased suspended solids due to the presence of priority pollutants led to operational problems in maintaining a steady mean cell residence time except in the case of 4-chloro,3-methyl phenol. Presence of 4-chloro,3-methyl phenol did not upset the steady mean cell residence time.

REFERENCES

1. Barth, Edwin F. and Robert L. Bunch. "Biodegradation and Treatability of Specific Pollutants." EPA-600/9179-034, Oct., 1979.

2. Tabak, H. H. and E. F. Barth. "Biodegradability of Benzidine in Aerobic Suspended Growth Reactors." Journal Water Pollution Control Federation, Vol. 50, No. 3, March 1979, p. 552.

3. Strier, Murray P. EPA Internal Report, June, 1977.

4. Standard Methods for the Examination of Water and Wastewater. 14th Ed. American Public Health Association, New York.

ACKNOWLEDGMENT

This study was funded by the United States Environmental Protection Agency Research Grant No. R-805242.

PB83-142216

THE TREATMENT OF COMBINED INDUSTRIAL AND DOMESTIC WASTEWATER FOR REUSE IN SOUTH AFRICA

J. van Leeuwen, L.R.J. van Vuuren, J.F.J. van Rensburg,
and A.J.R. du Plessis
National Institute for Water Research of the Council for Scientific
and Industrial Research, P. O. Box 395, Pretoria 0001,
Republic of South Africa

ABSTRACT

South Africa is a country with limited water resources. Consequently, conservation measures, including the reclamation of water from both domestic and industrial wastewater have been investigated. This paper describes the experience gained on various South African water reclamation plants, namely a 32,000 m^3/d plant near Springs, east of Johannesburg, which produces water for bleached pulp processing from domestic-industrial wastewater treated in a biofilter plant; a 12,000 m^3/d plant near Durban, which produces water for fine paper production from domestic-industrial wastewater from an activated sludge plant; the 4,000 m^3/d Stander plant in Pretoria, which produces potable water from biofilter and activated sludge effluents with little industrial pollution; a 300 m^3/d pilot plant near Cape Town, which produces a high-quality water from biofilter effluent of mainly industrial origin using an integrated physical-chemical-biological process; and a 60 m^3/d pilot plant in Pretoria which uses an integrated physical-chemical-biological process to produce water of potable quality from settled wastewater of mainly domestic origin. It was proved through inoculation of typical industrial pollutants that this process could successfully remove all heavy metals and various common organic compounds. All unit processes employed were necessary and important for the removal of at least one pollutant.

INTRODUCTION

Despite the country's mineral riches, South Africa has a shortage of water resources, particularly in the industrial growth centers. The Vaal River, for instance, a river of modest flow (1,2 x 10^9 m^3/a) (1), is the main source of water supply to more than 5 million people in the industrial heartland of the Pretoria-Witwatersrand-Vereeniging area. It is therefore not surprising that the reclamation of water from wastewater (including industrial effluents), for agricultural and industrial reuse, has become essential as a means of supplementing existing water sources.

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

REPRESENTATIVE WATER RECLAMATION PLANTS IN SOUTH AFRICA

The Sappi plant near Springs

The Enstra mill of the South African Pulp and Paper Industries Limited (SAPPI), situated near Springs on the eastern Witwatersrand, has no water supply on site. Underground water in the region originates from dolomitic material and is therefore too hard for paper-making. The nearest source of water of an acceptable quality is about 95 km. away (Rand Water Board). About 30% of the production (some 600 t/d) is soda-oxygen pulp, while fine paper constitutes less than a third of the production. Since most of the process water therefore need not be of the best quality, SAPPI built a 32,000 m^3/d (8,5 mgd) reclamation plant to produce an industrial feed water from secondary effluent from domestic sewage.

The influent to the local wastewater treatment plant consists of domestic wastewater combined with industrial effluents from engineering and metal finishing operations and from a meat-packing factory. The effluent from this plant serves as the feed to SAPPI's reclamation plant (Fig. 1). Coagulation with about 10 mg/L aluminium sulphate (as Al) and flocculation with 1,0 mg/L polyelectrolyte give excellent flocculation and separation by flotation. Marginal chlorination serves to polish the product. Sodium hydroxide (less than 10 mg/L) is added for stabilization purposes.

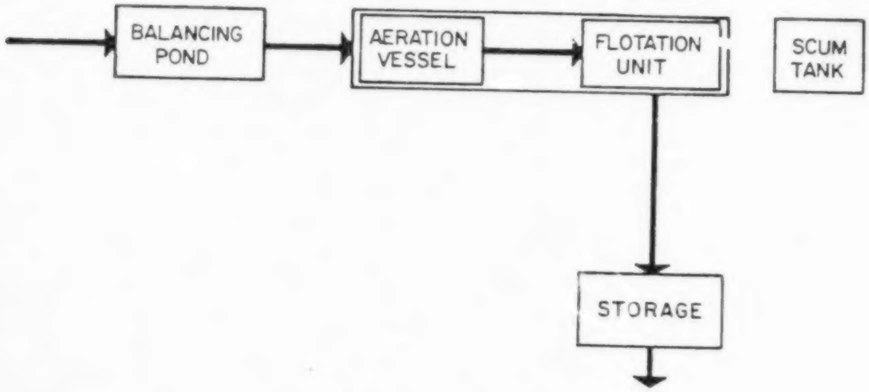


Figure 1. Flow diagram of the SAPPI water reclamation plant, Springs (32,000 m^3/d)

The reclamation process not only lessens turbidity and improves color, but also removes much of the chemical oxygen demand (COD), detergents, phosphates, iron, copper and chromium. Brightness of test sheets of paper compared favorably with those prepared from high quality Rand Water Board water. About 2 c/m^3 is being saved by using reclaimed water instead of Rand Water Board water (2).

Problems encountered with high concentrations of coloring matter in the effluent from certain industries have been solved by diverting these effluents to other wastewater treatment plants.

The Mondi plant near Durban

The Mondi paper mill near Durban comprises a groundwood pulp mill and three paper machines for the production of about 750 t/d of newsprint and fine paper. A good quality water, low in turbidity and color is required for the production of fine paper. Dissolved organics, detergents, and phosphates may all cause specific problems and should be present in low concentrations only.

The mill was established on an industrial site bought from the Durban Corporation. A condition of sale was that a minimum of 9,000 m^3/d of secondary effluent be used in the process. A reclamation plant of 12,000 m^3/d (3 mgd) was constructed to produce a high-quality industrial water from activated sludge effluent. The influent to the wastewater treatment plant consists of equal proportions of industrial and domestic effluent (3).

The unit processes employed at the Mondi water reclamation plant can be seen in Figure 2 and involve the following:

1. Aluminium sulphate coagulation (6 mg/L as Al, supplemented with 55 mg/L sulphuric acid, 25 mg/L lime and 2 mg/L floccotan polyelectrolyte),
2. Upflow clarification (at 1 m/h) and sodium hydroxide stabilization,
3. Foam fractionation,
4. Primary chlorination,
5. Pressure sand filtration,
6. Activated carbon treatment (with in situ regeneration facilities),
7. Final chlorination and clear water storage.

The reclamation process reduces suspended material to virgually zero, phosphates from 6,3 to 0,6 mg/L, detergents almost completely, COD by about 50% to an average of 43 mg/L and improves the color from 57 Hazen units to 7 (average values in 1976) (3).

A major difficulty was the presence of color in the wastewater from textile wet-processing. This resulted in shortened actived carbon utilization cycles and higher treatment costs. Stricter effluent control measures taken by the Durban Corporation led to a greater improvement in plant performance.

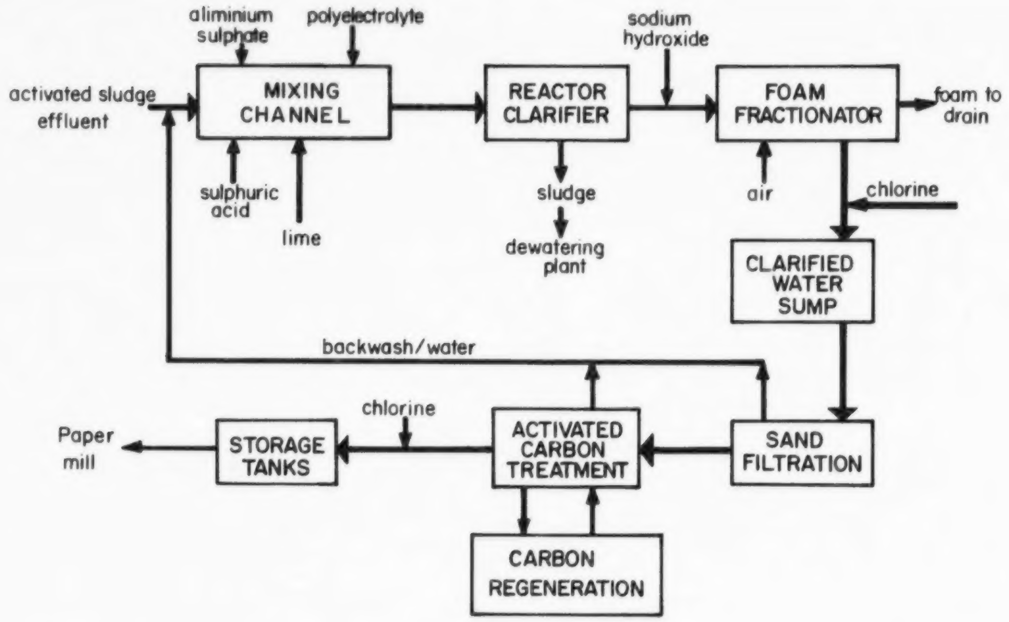

aliminium sulphate
polyelectrolyte
sodium hydroxide
activated sludge effluent
MIXING CHANNEL
REACTOR CLARIFIER
FOAM FRACTIONATOR
foam to drain
sulphuric acid
lime
sludge
dewatering plant
air
chlorine
CLARIFIED WATER SUMP
backwash/water
chlorine
Paper mill
STORAGE TANKS
ACTIVATED CARBON TREATMENT
SAND FILTRATION
CARBON REGENERATION

Figure 2. Flow diagram of the Mondi water reclamation plant, Durban (12,000 m^3/d)

The cost of Mondi's reclaimed water is very similar to that of potable water, and includes the price of the secondary effluent purchased from Durban Corporation. Mondi purchases both its potable water and secondary effluent from Durban Corporation. Nevertheless, Mondi prefers using reclaimed water as production is then less dependent on potable supplies that could be interrupted in emergencies. In 1976, when floods necessitated a 29-day shutoff of potable water supplies, and neighboring industries ground to a halt, production at Mondi remained at full capacity. Mondi is at present carrying out major extensions to its paper mill in Durban and is considering increasing the use of treated wastewater as mill water supply (A. Giampietri, 1980 - personal communication).

The Stander water reclamation plant, Pretoria

This 4,000 m^3/d facility (1 mgd) for the production of potable water from secondary effluent was primarily intended for research and development.

The process was originally designed to treat biofilter humus tank effluent (from the treatment of mainly domestic wastewater). The unit processes involved (4) were high lime coagulation, primary clarification in a flocculation reactor/sedimentation tank, quality equalization in a large holding tank, ammonia air stripping in a slatted tower, recarbonation, secondary clarification, sand filtration, breakpoint chlorination, activated carbon absorption, final chlorination and stabilization (Fig. 3).

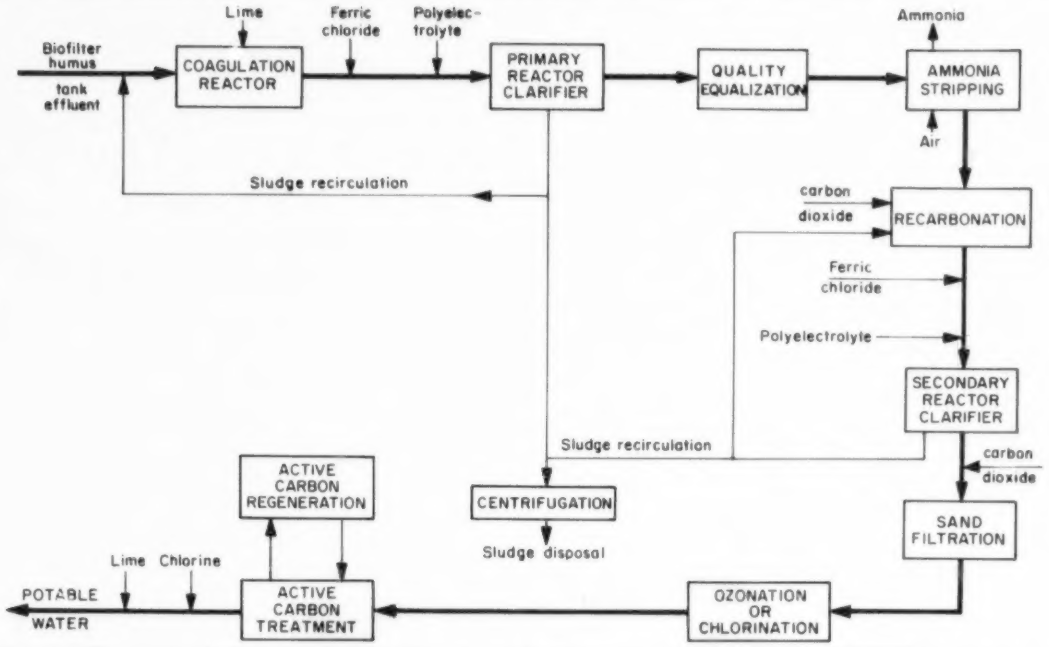

Biofilter humus tank effluent
Lime
COAGULATION REACTOR
Ferric chloride
Polyelectrolyte
PRIMARY REACTOR CLARIFIER
QUALITY EQUALIZATION
Ammonia
AMMONIA STRIPPING
Air
Sludge recirculation
carbon dioxide
RECARBONATION
Ferric chloride
Polyelectrolyte
SECONDARY REACTOR CLARIFIER
Sludge recirculation
carbon dioxide
CENTRIFUGATION
Sludge disposal
SAND FILTRATION
ACTIVE CARBON REGENERATION
Lime
Chlorine
POTABLE WATER
ACTIVE CARBON TREATMENT
OZONATION OR CHLORINATION

Figure 3. Flow diagram of the Stander water reclamation plant, Pretoria, treating biofilter effluent (4,000 m^3/d).

It was found that high lime clarification was very effective, not only for the removal of turbidity, but also for partial disinfection and for converting ammonium ions to the molecular form for later air stripping. Quality equalization not only resulted in attenuation of diurnal quality variations but was efficacious in partial ammonia stripping through surface aeration and partial stabilization through carbon dioxide adsorption from ammonia (6), but was economical only at ammonia concentrations higher than 5 mg/L (7). Recarbonation followed by secondary settling at a pH of about 10 resulted in partial softening and excellent clarification. Sand filtration finally reduced turbidity to about 0,7 Jackson turbidity units (JTU). Breakpoint chlorination removed ammonia and resulted in elimination of all pathogens (7). Activated carbon effectively removed most of the dissolved organic carbon and COD to values consistently below 15 mg/d (8). Final chlorination and stabilization resulted in a water of excellent potable quality (9).

The total cost of the reclaimed water was $0.30/$m^3$ in 1977. At the present escalation of costs of goods and services, the cost would be $0.42/$m^3$. An analysis of costs reveals that scaling up of the operation to 40,000 m^3/d would reduce reclamation costs (1980) to $0.20/$m^3$ (or $0.77 per 1,000 U.S. gallons). The costs include amortization of capital (over 20 years at 11% interest on balance) and all operational and maintenance costs. Scaling up was done according to the method of Guthrie (10).

The Stander plant has also been used in more recent years to reclaim water from activated sludge effluent (Fig. 4). The more consistent quality and lower ammonia concentrations in this effluent enabled elimination of quality equalization and ammonia stripping (11). The need for a high pH to facilitate ammonia stripping was eliminated and opened up the possibility of using ferric chloride or aluminium sulphate as coagulant, which removed the need for recarbonation. The smaller dosages of ferric chloride or aluminium sulphate required, led to a saving in chemicals, while similar dosing mechanisms reduced maintenance costs. The additional safety barrier against pathogens afforded by the high lime treatment could be replaced by prechlorination between the two clarification stages. Ozonation between sand filtration and activated carbon treatment resulted in a fourfold increase in operational life of the activated carbon (12).

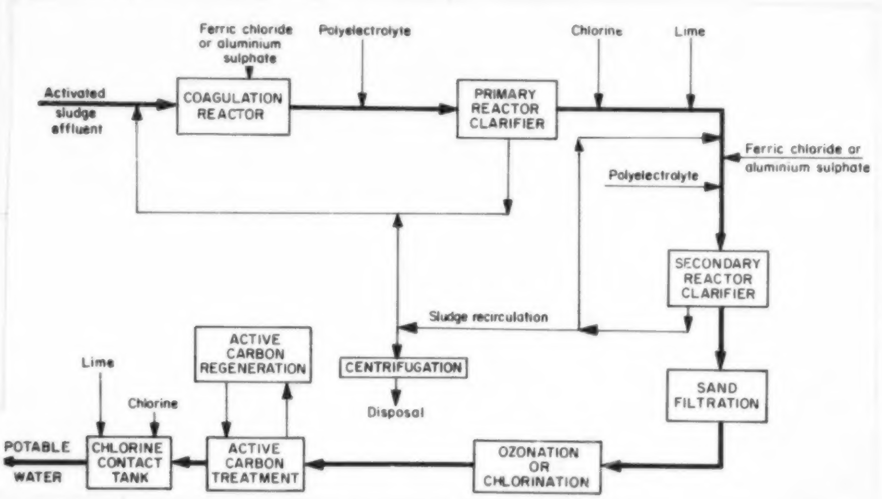

Ferric chloride or aluminium sulphate
Polyelectrolyte
Chlorine
Lime
Activated sludge effluent
COAGULATION REACTOR
PRIMARY REACTOR CLARIFIER
Ferric chloride or aluminium sulphate
Polyelectrolyte
SECONDARY REACTOR CLARIFIER
Sludge recirculation
ACTIVE CARBON REGENERATION
CENTRIFUGATION
Disposal
SAND FILTRATION
Lime
Chlorine
POTABLE WATER
CHLORINE CONTACT TANK
ACTIVE CARBON TREATMENT
OZONATION OR CHLORINATION

Figure 4. Flow diagram of the Stander water reclamation plant, Pretoria, treating activated sludge effluent (4,000 m^3/d)

Total costs could be reduced to \$0.33/m^3 (4,000 m^3/d scale) or \$0.13/m^3 on a 40,000 m^3/d scale (or \$0.47 per 1,000 U.S. gallons). Biological, chemical, epidemiological, toxicological, carcinogenic, teratogenic and mutagenic tests have been conducted on the final water produced by both process configurations (13, 14, 15, 16). No adverse effects could be established and in fact it was proved that the quality of the reclaimed water conformed to all the quality criteria laid down by various regulatory bodies, including the U.S. Environmental Protection Agency.

A plant to produce potable water from biofilter maturation pond effluent for direct distribution was commissioned in Windhoek in 1969. The process was very much the same as that applied at the Stander plant (17). Since 1979, the Windhoek plant has also changed to the reclamation of potable water from activated sludge effluent, and has already adopted most of the process modifications (apart from ozonation) possible on the Stander plant. Since commissioning, the plant has intermittently contributed up to 20% of Windhoek's potable water needs (18). According to the City Engineer, the only

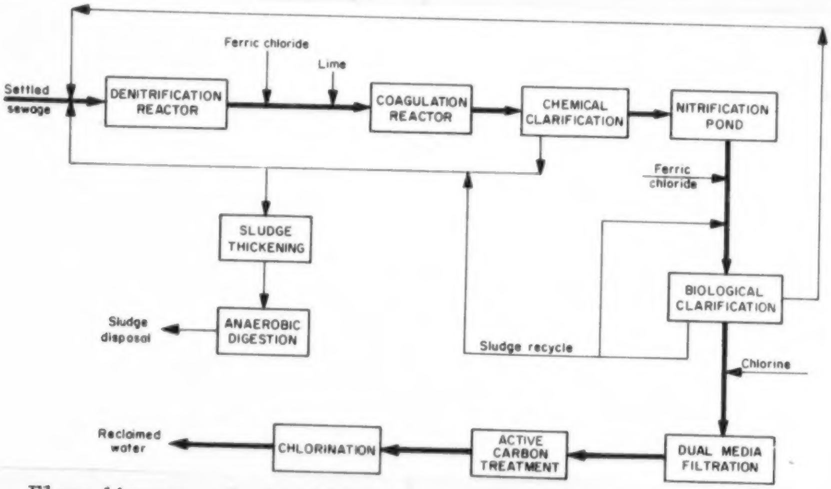
EPA-287 (Cin.)
(4-76)

complaints about reclaimed water quality were received when the reclamation plant was not in operation (A. J. Clayton, 1979 - personal communication).

The LFB pilot plant, Pretoria

The National Institute for Water Research (NIWR) developed this 60 m^3/d pilot plant to investigate the feasibility of integrating biological wastewater treatment with physico-chemical water reclamation. The original process employed lime coagulation and flotation as pretreatment for activated sludge treatment and was called the lime flotation biological (LFB) process (19). Recent modifications included ferric chloride coagulation followed by sedimentation and partial denitrification (20).

The incoming raw screened wastewater (7 to 10% industrial) is brought into contact with recirculation streams from succeeding unit processes (including fully nitrified effluent from the aerobic activated sludge process unit) resulting in denitrification (Fig. 5). After ferric chloride coagulation and flocculation, followed by sedimentation, the effluent passes through a surface aerated activated sludge pond and then undergoes clarification (after a secondary ferric chloride addition). Part of the sludge from the clarifier is returned to the activated sludge pond. Part of the underflows of the two clarifiers are returned to the denitrification unit. The excess sludges are digested anaerobically.



Ferric chloride
Lime
Settled sewage
DENITRIFICATION REACTOR
COAGULATION REACTOR
CHEMICAL CLARIFICATION
NITRIFICATION POND
Ferric chloride
SLUDGE THICKENING
BIOLOGICAL CLARIFICATION
Sludge disposal
ANAEROBIC DIGESTION
Sludge recycle
Chlorine
Reclaimed water
CHLORINATION
ACTIVE CARBON TREATMENT
DUAL MEDIA FILTRATION

Figure 5. Flow diagram of the LFB pilot plant, Pretoria (60 m^3/d)

The overflow from the activated sludge clarifier is prechlorinated and passed through a roughing filter and a dual media filter. The filtered effluent then passes through an activated carbon column and is chlorinated beyond breakpoint.

The pilot plant proved highly successful for the production of a good quality water from untreated wastewater. The COD was reduced by more than 97% to less than 10 mg/L (26 mg/L before activated carbon treatment). Ninety eight percent of the nitrogen (as total Kjeldahl nitrogen) was removed and the ammonia concentration in the final water was less than 0,2 mg/L.

Phosphate was removed to less than 0,2 mg/L. The nitrate level was slightly high at 11 mg/L (as N), but could be improved by increasing the recycle ratio of nitrified effluent to the anaerobic reactor. The anaerobic treatment could reduce the influent sulphate concentration by about 50%. Almost 80% of the surfactants (measured as linear alkylbenzenes) were removed. The chloride and total dissolved solids levels increased owing to ferric chloride addition and chlorination.

A capital, operational and maintenance cost estimate for this small plant is possible as some of the unit processes are similar to those of the Stander plant, for which these costs are available. The total capital cost (4,000 m^3/d) on a discounted cash flow basis would be \$0.095/m^3 and the total chemical cost \$0.08/m^3 (based on data published by van Vuuren and Taljard, (20)). When all the other costs (electricity, operation, maintenance and sludge disposal) are taken into account, the total cost is \$0.36/m^3, or \$0.15/m^3 on a 40,000 m^3/d scale. Although this cost is marginally higher (about 10%) than that of reclamation of water from secondary effluent, it should be appreciated that it includes the cost of secondary treatment (normally 4 to 7c (U.S.)).

Athlone pilot water reclamation plant, Cape Town

A 300 m^3/d pilot plant, based on the original process development of the LFB plant, was constructed to investigate water reclamation from wastewater with a large proportion of industrial effluent. The Athlone sewage works has heavily overloaded trickling filters which produce a poor effluent with a COD of 220 mg/L, ammonia concentration of 36 mg/L and nitrate concentration below 1 mg/L (as N) on average (20).

This effluent serves as feed water to the pilot plant. The reclamation process is initiated with high lime coagulation and flocculation with ferric chloride and polyelectrolyte, followed by clarification (Fig. 6). This is followed by air stripping of ammonia before a surface aerated activated sludge unit. Ferric chloride and polyelectrolyte are then added before the biological clarifier. Part of the underflow is returned to the activated sludge unit, while the remainder is returned to the primary coagulation reactor together with the return sludge from the chemical clarifier. The effluent is then chlorinated, sand filtered and passed through activated carbon units before final chlorination.

The reclaimed water is of a good quality, with ammonia concentrations of less than 0,2 mg/L (as N); COD, 22 mg/L; and total phosphate, 0,8 mg/L. No coliforms, *Escherischia coli*, *Clostridium perfringens*, *Pseudomonas aeruginosa*, faecal streptococci or coliphages have been found in the reclaimed water. The total dissolved solids concentration is about 800 mg/L, mainly owing to the presence of chloride (233 mg/L as Cl), total hardness (about 200 mg/L as $CaCO_3$) and sulphate (84 mg/L as SO_4). The turbidity is lowered to 1,0 JTU, while the color is reduced from 205 in the biofilter effluent to 9 Hazen units. The process removed 99.5% of the ammonia, 90% of the organic nitrogen, 90% of the COD and more than 90% of the phosphate. Iron, manganese and magnesium are also partly removed, while there is a large increase in nitrate concentration (20).

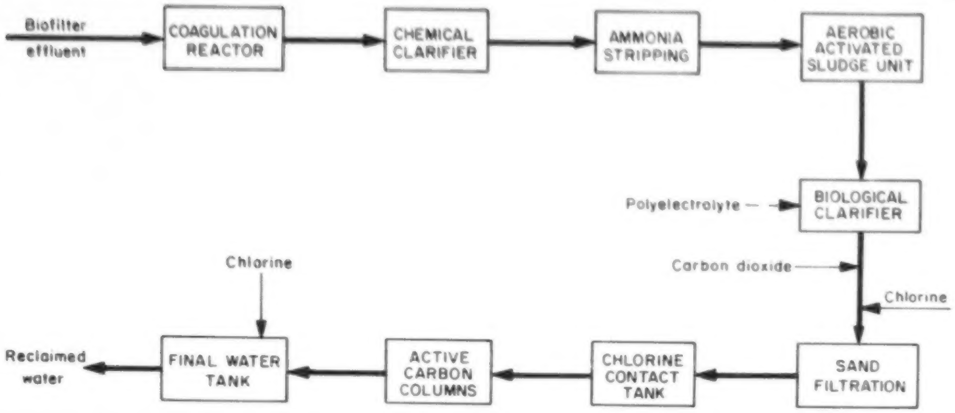

Biofilter effluent
COAGULATION REACTOR
CHEMICAL CLARIFIER
AMMONIA STRIPPING
AEROBIC ACTIVATED SLUDGE UNIT
Polyelectrolyte
BIOLOGICAL CLARIFIER
Carbon dioxide
Chlorine
SAND FILTRATION
CHLORINE CONTACT TANK
ACTIVE CARBON COLUMNS
Chlorine
FINAL WATER TANK
Reclaimed water

Figure 6. Flow diagram of the Athlone pilot water reclamation plant, Cape Town (300 m^3/d)

The chemical dosing cost can be calculated by using data provided by van Vuuren and Taljard (20) at \$0.14/m^3. If the projected full-scale capital, operational, energy and maintenance costs are included, the total cost will amount to \$0.44/m^3 (4,000 m^3/d) or \$0.21/m^3 (40,000 m^3/d).

UNIT PROCESS SELECTION FOR SPECIFIC POLLUTANT REMOVAL

The operational results of various pilot and small reclamation plants demonstrate their capability to produce the desired quality water for potable or industrial purposes, but since the raw waters are often mainly of domestic origin, it was not always possible to predict the capacity of the processes to cope with industrial pollutants. Two pilot plants were used to study the efficacy of various unit processes in removing pollutants inoculated individually, namely the LFB (Fig. 5) and the BPC pilot plant, which was essentially a 50 m^3/d test facility based on the same process as the Stander plant treating biofilter humus tank effluent (Fig. 3).

Pollutants dosed

Nineteen different organic compounds (some highly toxic) were dosed at nominal feed concentrations of 40 ug/L each for 30 h or longer (13, 21). In parallel experiments with trace metals and other chemicals, loads as high as 0,5 mg/L cyanide and phenol (22, 23), 5 mg/L chromium, 1 mg/L cadmium and 150 ug/L mercury, arsenic and selenium (24) were inoculated. The efficacy of the various unit processes employed in both plants is discussed below.

Denitrification

The denitrification reactor as employed in the LFB pilot plant (with recirculated nitrified effluent and chemical and biological sludges) removed more than 98% of the metal ions with the exception of barium, which, with phenol, was only partially removed. The recycling procedures in the plant caused a buildup of cyanide within the sludge. Significant removals of up to 80% for 12 of the 19 organic compounds were obtained, with an average removal of 37%. No significant buildup of these compounds through sludge recycling was encountered.

Ferric chloride coagulation and clarification

This process also resulted in individual removal of more than 98% of the metal ions, with the exception of barium (85%). Seventy-five percent of the phenol was removed, while cyanide increased by 300% owing to sludge recycling. Significant removals of up to 85% for 15 of the compounds in the unit process feed, with an average of 35%, were obtained.

Aerobic activated sludge and biological clarification

Complete removal of mercury and most of the lead, cadmium, arsenic and selenium, as well as phenol, was achieved in these units. The removal of barium, hexavalent chromium and cyanide was poor. Up to 100% removal, with an average of 69% for 16 of the organic compounds, was achieved. Naphtalene, dichlorvos, anthracene, cresol, chlorophenol and ß-naphtol were removed to below their detection limits. The remainder (about 1%) of the acenaphthene, hexadecane, dieldrin and phenol, represent nominal trace concentrations of 5 ug/L in the water.

Pre-chlorination and two-stage filtration

All of the lead, and most of the mercury, arsenic and selenium were removed. Barium, hexavalent chromium and phenol removal was ineffective, while 80% of the cyanide was removed. The pre-chlorination caused a removal or breakdown of more than 99% of the polynuclear hydrocarbons, as well as 98 to 100% of the phenolic compounds. Filtration was generally ineffective for the removal of the inoculated organic compounds, with the exception of those that would adsorb to suspended matter in the water, for example, the polynuclear aromatic compounds.

Activated carbon treatment

This proved to be an effective barrier against the passage of cadmium, silver, lead, mercury, arsenic, cyanide and phenol. Most of the barium and selenium was also removed, but no removal of hexavalent chromium was achieved. All of the inoculated organic compounds were removed completely.

Final chlorination

This final unit process was not studied separately because of the short retention time and duplication of results achieved with pre-chlorination. In the light of the removal rates achieved with activated carbon treatment, this study would have been superfluous.

High lime coagulation and clarification

This unit process was only employed on the BPC pilot plant as an initial treatment step for biofilter humus tank effluent. It was very effective for the removal of lead, cadmium and mercury and to a lesser extent for zinc, while copper and cyanide were ineffectively removed. The removal of organic material closely resembled that of the other flocculation and sedimentation processes.

DISCUSSION

It is possible to reclaim water from wastewater (including industrial wastewater) for many applications. Water can be reclaimed to conform to any quality criteria, including those for potable water. In many cases, reclaimed water may be an economically viable alternative to water from conventional, potable supplies. When reclaiming water from combined industrial and domestic wastewater, cooperation between local authorities and industry is a vital part of the success of the operation.

It may prove advantageous to consumers to be partially dependent on reclaimed water; disruption in supply from one of the sources can then be less damaging than disruption of a single supply.

In South Africa, the cost of potable reclaimed water is already approaching that of drinking water obtained by conventional purification of surface water. The average price the consumer paid for potable water in the eight largest South African cities was $0.24/m^3 in 1979, the major portion of this cost being attributable to distribution and revenue to local authorities. If distribution costs and revenue are to be added to the cost of reclaimed water, it will have to be sold at a higher price than this. In many cases, however, pumping costs of water from distant sources are high; and it may well prove economical to distribute reclaimed water from wastewater sources which are usually easily accessible.

The quality requirements for many industrial processes are lower than for domestic reuse purposes. Water reclaimed from wastewater for a particular industrial reuse will therefore be a cheaper alternative than the potable supply. The reclamation process should include only those unit processes essential to achieve the specific quality objectives of the particular industry. If the removal of hexavalent chromium is required, for instance, this can be achieved by ferric chloride clarification, but activated carbon adsorption would be ineffective. Cyanide and phenol can be effectively removed more economically by a combination of activated sludge treatment and ferric chloride clarification, while cyanide could be removed at lower cost by means of breakpoint chlorination. Activated carbon is effective for the removal of a broad spectrum of pollutants, particularly organic compounds, but many of these compounds can also be removed by the activated sludge process. Nevertheless, activated carbon is indispensable as a final contaminant barrier in the production of potable water from wastewater.

Consideration should be given to the reuse of wastewater without intermediate treatment. The variety of industrial processes and relatively low irrigation water quality requirements in the Pretoria-Witwatersrand-Vereeniging area lend themselves to water reuse without costly intermediate treatment. Only in cases where no end user of a lower quality water is available should reclamation of water from wastewater be considered.

Water reclamation not only offers an extension of the usefulness of a given quantity of water, but can also play an important role in combatting pollution. There are distinct environmental advantages to concentrating toxic pollutants in sludge or on activated carbon as opposed to discharge into rivers and streams particularly when reclaiming water from industrial effluents. Prevention of pollution is usually better than its cure also from an economical point of view.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the following persons for providing data and for valuable suggestions:

Mr. R. Smith - National Institute for Water Research;
Mr. M. L. Siebert - National Institute for Water Research;
Mr. J. W. Funke - National Institute for Water Research;
Mr. E. J. Smith - Research Laboratory, SAPPI Fine Papers (Pty) Ltd;
Dr. A. Giampietri - Mondi Paper Company;
Mr. A. F. Zunckel - Department of Water Affairs; and
Dr. F. C. Viljoen, Rand Water Board.

This paper is presented with the approval of the Director of the National Institute for Water Research.

REFERENCES

1. Department of Water Affairs. *River Flow Data. October 1960 to September 1970.* Hydrological Information Publication No. 10, Government Printer, Pretoria.

2. van Vuuren, L.R.J., Funke, J.W. and Smith, L. The full-scale refinement of purified sewage for unrestricted industrial use in the manufacture of fully-bleached Kraft pulp and fine paper. *Advances in Water Pollution Research* (Ed. S.H. Jenkins). Proceedings of the 6th International

Conference of the IAWPR, Jerusalem, 8-23 June 1972, 627-636.

3. Giampietri, A., Funke, J.W. and Voysey, J.A. The reclamation of process water from sewage effluent and the reuse of mill effluents and solids at Mondi Paper Company, Durban, South Africa. *Prog. Water Technol.* 10, (1/2), 1978, 113-121.

4. Stander, G.J., van Vuuren, L.R.J. and Dalton, G.L. Current status of research on wastewater reclamation in South Africa. *Wat. Pollut. Contr.*, 70, (2), 1971, 213-222.

5. van Vliet, B.M., Wiechers, H.N.S. and Hart, O.O. The efficacy of an equalization pond in a water reclamation system. *Prog. Water Technol.*, 9, 1978, 443-454.

6. Henzen, M.R., Stander, G.J. and van Vuuren, L.R.J. The current status of technological developments in water reclamation. *Prog. Water Technol.*, 3, 1973, 307-318.

7. van Leeuwen, J. and Ross, W.R. Refinement of a chlorination process unit in water reclamation: Technological and cost implications. *Prog. Water Technol.*, 10, (1/2), 1978, 579-585.

8. van Vliet, B.M. Carbon regeneration in South Africa. *Prog. Water Technol.*, 10, (1/2), 1978, 555-564.

9. van Leeuwen, J. Final treatment. Chapter 12, *Manual for Water Renovation and Reclamation.* CSIR Technical Guide K42, National Institute for Water Research, Pretoria.

10. Guthrie, K.M. Data and techniques for preliminary capital cost estimating. *Chemical Engineering*, March 24, 1969, 114-142.

11. Prinsloo, J., van Blerk, S.H.V. and van Leeuwen, J. Comparative reclamation of potable water from biofilter and activated sludge effluents at the Stander water reclamation plant. *Prog. Water Technol.*, 10, (1/2), 1978, 81-87.

12. van Leeuwen, J. *The design and application of a packed column ozone absorber in water reclamation.* Presented at the 4th World Congress of the International Ozone Association, Houston, Texas, 26-29, November 1979.

13. van Rensburg, J.F.J., van Rossum, P.G. and Hattingh, W.H.J. The occurrence and fate of organic micropollutants in a water reclaimed for potable reuse. *Prog. Water Technol.*, 10, 1978, 41-48.

14. Grabow, W.O.K., Burger, J.S. and Nupen, E.M. Evaluation of acid-fast bacteria, *Candida albicans*, enteric viruses and conventional indicators for monitoring wastewater reclamation systems. To be presented at the Tenth International Conference of the IAWPR, Toronto, 23-27, June 1980.

15. Denkhaus, R., Grabow, W.O.K. and Prozesky, O.W. Removal of mutagenic compounds in a wastewater reclamation system evaluated by means of the Ames *Salmonella* microsome Assay. To be presented at the Tenth International Conference of the IAWPR, Toronto, 23-27, June 1980.

16. van Rensburg, S.J., Hattingh, W.H.J., Siebert, J.L. and Kriek, N.P.J. Biological testing of water reclaimed from purified sewage effluents. *Prog. Water Technol.*, 10, 1978, 347-356.

17. van Vuuren, L.R.J., Henzen, M.R., Stander, G.J. and Clayton, A.J. The full-scale reclamation of purified sewage effluent for the augmentation of the domestic supplies of the City of Windhoek. *Prog. Water Technol.*, 2, 1971, 32-41.

18. van Vuuren, L.R.J., Clayton, A.J. and van der Post, D.C. *Current status of water reclamation at windhoek*. Presented at the 51st Annual Conference of the Water Pollution Control Federation, Anaheim, 1-6 October, 1978.

19. van Vuuren, L.R.J., Ross, W.R. and Prinsloo, J. The integration of wastewater treatment with water reclamation. *Prog. Water Technol.*, 9, 1977, 455-466.

20. van Vuuren, L.R.J. and Taljard, M.P. *The reclamation of industrial/domestic wastewaters*. Presented at the American Water Reuse Symposium, Washington, D.C., 25-30 March, 1979.

21. van Rensburg, J.F.J., Hassett, A., Theron, S. and Wiechers, S.G. The fate of organic micropollutants through an integrated wastewater treatment/water reclamation system. To be presented at the Tenth International Conference of the IAWPR, Toronto, 23-27 June, 1980.

22. Siebert, M.L. The fate of phenol, cyanide, flouride and nitrate through an integrated physical-chemical-biological water reclamation system. (in preparation).

23. Smith, R., Siebert, M.L. and Hattingh, W.H.J. Removal of inorganic pollutants from wastewater during reclamation for potable reuse. *Water S.A.*, 6, 1980.

24. Smith, R. and Wiechers, S.G. Elimination of toxic metals from wastewater by an integrated wastewater treatment/water reclamation system. To be presented at the Biennial Conference of the Institute of Water Pollution Control (Southern Africa Branch), Pretoria, 2-6 June, 1980.

PB83-142224

USE OF GRANULAR ACTIVATED CARBON TO TREAT MUNICIPAL WASTEWATER RECEIVING INDUSTRIAL FLOW

P. B. DeJohn
J. P. Black
R. W. Edwards
ICI Americas Inc.
Wilmington, Delaware 19897

INTRODUCTION

Generally, for a plant to completely reuse their wastewater, high pollutant (BOD, COD, color, etc.) removals must be attained. Granular activated carbon, in either a physical chemical or a teriary mode, has been established as an effective method of reducing pollutants to low levels. When zero discharge standards are imposed, more and more plants will be turning to granular activated carbon treatment.

In an effort to assist anyone considering granular activated carbon treatment, this paper will discuss the following:

- How to evaluate granular activated carbon.
- Adsorption data developed on municipal wastes.
- Adsorption data developed on various types of industrial wastes.
- The effect of thermal regeneration on the properties and performance of granular activated carbon.
    - How to select the best carbon for a given system.
    - How to prevent undersizing a carbon system.

Possible symbiotic applications resulting from the thermal reactivation of granular carbon include:

- Utilization of the carbon fines in other wastewater processes.
- Utilization of the heat content of the exit gases in other plant processes.

EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

TEXT

How to Evaluate Granular Activated Carbon Isotherms

In order to determine if granular activated carbon can effectively treat a given waste, one should first run an adsorption isotherm. An isotherm is a plot on log paper showing the relationship between the amount of impurities adsorbed on a unit weight of activated carbon and the amount of impurities remaining in the wastewater.

To run an isotherm, carefully weighted quantities of carbon are added to a constant volume of wastewater. The carbon-wastewater mixtures are agitated vigorously for about 30 minutes. The carbon is then removed by filtration. The treated water is analyzed for the level of impurities and the amount adsorbed is found by difference.

The purpose in running an isotherm is to determine if carbon can reduce the impurity level to the desired quantity. This relatively short screening technique can usually show whether it is worth conducting time-consuming column studies. Adsorption isotherms very rarely yield data reliable enough to use for granular carbon system design because:

- Granular activated carbon is a good biological growth media. Carbon in a column will develop a biological growth which will improve BOD removals through the bed. Isotherms cannot predict these removals.

- Adsorption isotherms are equilibrium tests. The carbon will come into equilibrium with all of the pollutants in the particular wastewater sample being treated. Never does the carbon come into equilibrium with the feed concentration in an isotherm test.

On the other hand, adsorption in a granular column is a dynamic phenomenon. As the wastewater moves through the granular bed, the carbon is continually adsorbing the more readily adsorbable organics and desorbing the less adsorbable organics. This phenomenon has also been reported elsewhere (1). Consequently, in a granular carbon system, if the contact time between the carbon and the wastewater is not adequate, the more difficult to adsorb organics will bleed through the bed because of this desorption phenomenon.

Obviously, when designing a granular carbon system, one attempts to determine the optimum contact time to minimize or prevent this occurrence. This information cannot be obtained from an isotherm!

Column Tests

The test consists of moving wastewater through at least four columns in series containing granular carbon and measuring the amount of pollutant remaining in each column effluent. Samples of the feed entering the lead column and also of the effluent from each column should be taken at regular intervals (at least once per day). The "percent pollutant remaining" is plotted for each column against time or volume of water treated. When the pollutant concentration of the effluent from the last column in the series

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

becomes greater than the standard allows (breakthrough), the test can be stopped. Enough information is then available to:

- Determine the optimum contact time between the carbon and the wastewater. The contact time is the major design parameter needed to size the adsorption portion of the granular carbon system.

- Determine the carbon usage or exhaustion rate. The carbon usage rate will tell one how much carbon must be reactivated per day. It is a major design parameter needed to size the regeneration portion of the granular carbon system.

- Estimate preliminary investment and operating costs for a full-scale plant.

Detailed methods on how to run an isotherm, how to conduct a column study and how to analyze the data from a column study to adequately size a granular carbon system are well documented in the literature (2), (3), (4).

Adsorption Data Developed on Municipal Wastes

ICI United States Inc. has conducted more than 50 comparative pilot granular carbon studies on various types of municipal and industrial wastewaters.

Tables 1 and 2 show comparative adsorption data from two studies conducted on domestic wastewater at Marshall, Texas and Cortland, New York. Equal volumes of carbon were compared in a tertiary mode at Marshall and a physical/chemical mode at Cortland. These data are typical of all the studies conducted on domestic wastewaters where we compared lignite and bituminous coal based granular activated carbons.

The data shows that both carbon types perform equally well on an equivalent volume basis when treating domestic wastestreams regardless of the treatment mode.

In the Marshall study, the carbons were compared through five adsorption and four regeneration cycles. At Cortland, the evaluation was terminated after 146 days and the effluents from the columns containing the two different carbon types were still suitable. Consequently, the final system loading would have been higher than reported.

In each study, the feed concentrations to the columns containing the lignite and bituminous coal carbons were the same. The effluent concentrations were, for all practical purposes, identical. The lignite carbon loaded substantially higher than the bituminous coal carbon in the Marshall study and slightly higher in the Cortland study.

Carbon loading is a measure of the pounds impurity removed per pound of carbon applied. Carbon loading reflects carbon capacity for a given waste. The carbon usage rate is a function of the carbon loading. The higher a

EPA-287 (Cin.)
(4-76)

TABLE 1 COMPARATIVE ADSORPTION DATA FROM A TERTIARY STUDY AT MARSHALL, TEXAS

Effluent from the plant's trickling filter was passed upflow through a sand filter and downflow through two 6" I.D. carbon columns in parallel at a linear flow rate of 6.9 gpm/ft.^{2} One column contained 10' of an 8 x 35 mesh lignite carbon and the other column 10' of a 12 x 40 mesh bituminous coal carbon. Empty bed contact time was 11 minutes in each column.

The carbons were compared through five adsorption and four regeneration cycles. Regeneration was done in a rotary tube laboratory activation furnace, and the spent carbons were regenerated to the apparent densities of the virgin carbons.

	First Adsorption Cycle (Virgin Carbon)	
	Lignite Carbon	Bituminous Coal Carbon
Avg. feed COD to carbon column, ppm	54.5	54.5
Avg. effluent COD from carbon columns, ppm	35.6	37.7
COD loading, lb. total COD/lb. carbon	0.312	0.230

	Average For All Five Adsorption Cycles	
	Lignite Carbon	Bituminous Coal Carbon
Avg. feed COD to carbon columns, ppm	80.9	80.7
Avg. effluent COD from carbon columns, ppm	58.1	58.8
COD loading, lb. total COD/lb. carbon	0.347	0.277

EPA-287 (Cin.)
(1-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

TABLE 2 COMPARATIVE ADSORPTION DATA FROM A PHYSICAL/CHEMICAL STUDY AT CORTLAND, NEW YORK

Effluent from the primary clarifier was fed to two sets of five 4" I.D. carbon columns in parallel at a linear flow rate of 4 gpm/ft.^{2} Each set of five columns was then operated downflow in series. Each column contained 3.2 ft. of carbon, giving a total bed depth of 16 ft. One set contained an 8 x 30 mesh lignite carbon and the other contained an 8 x 30 mesh bituminous coal carbon. Empty bed contact time was 30 minutes through each set of five columns.

The study was terminated after 146 days and the effluents from both sets of columns were still suitable. Consequently, the final system loading would have been considerably higher than reported.

	Lignite Carbon	Bituminous Coal Carbon
Avg. feed BOD to carbon columns, ppm	52.7	53.2
Avg. effluent BOD from carbon columns, ppm	7.3	7.5
BOD removed, %	86.0	85.9
BOD loading, lb. BOD/lb. carbon	0.55	0.53
Avg. feed COD to carbon columns, ppm	97.2	97.6
Avg. effluent COD from carbon columns, ppm	26.0	28.7
COD removed, %	71.1	68.9
COD loading, lb. COD/lb. carbon	0.86	0.81

9-1/8"
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

carbon loads, the longer it is able to remain in the adsorption cycle. Consequently, the carbon usage rate will be less and a smaller regeneration system might be justified.

Comparative Physical Properties of Lignite and Bituminous Coal Carbons

Tables 3 and 4 list the typical properties of 8 x 30 and 12 x 40 mesh lignite and bituminous coal carbons. The most significant differences are in total surface area, iodine number, molasses RE or molasses number, pore volume and bulk density.

Iodine number is a good measure of the surface area in the small pores (micropores). Micropores are defined as those having an effective radius of ≤ 20 A° (5).

Molasses RE or molasses number gives a good indication of the surface area in the transitional pore range. Transitional pores are defined as those pores having an effective radii ranging from 20 A° to 500 A°, and pores larger than 500 A° are defined as macropores (5).

Total surface area, as determined by the N_2 BET method (6), measures all of the above mentioned pore ranges.

Pore volume is a measure of the void space within the carbon particle--the holes, and is determined by mercury intrusion.

Bulk density is normally defined as the density of a carbon after it has been placed in an adsorber and has been washed and drained. It is the total dry weight of carbon divided by the total volume occupied by that carbon after washing and draining. Generally, the higher the pore volume, the lower the bulk density.

The adsorption data just reviewed indicates that total surface area is not a good predictor of how effectively a carbon will adsorb. Rather it would appear that available surface area in pores of a size similar to the size of the molecule to be adsorbed would best predict the effectiveness of a carbon.

Since the lignite carbon has a higher surface area in the transitional pore range than does the bituminous coal carbon, we concluded that breakthrough was occurring because these pores were becoming exhausted.

Others have reported similar findings. Abram stated that pore volume and surface area in the transitional pores are most used to remove organics from a liquid phase. He also reported that to determine the most effective carbon for a given application, the molecular size of the organic to be adsorbed should be compared to the surface area and pore volume distribution of the candidate carbons (7). The implication being that the best carbon will be one having the most surface area and pore volume in the desired range.

TABLE 3 TYPICAL PROPERTIES OF 8 x 30 MESH LIGNITE AND BITUMINOUS COAL CARBONS

	8 x 30 Mesh	
	Bituminous Coal Carbons (17, 18, 19)	Lignite Carbons
Total Surface Area (N_2 BET method) m^2/g	950-1050	500-650
Iodine Number, min.	950	500
Bulk Density, lbs./$ft.^3$ Backwashed and Drained	26	23
Particle Density Wetted in Water, g/cc	1.3-1.4	1.3-1.4
Pore Volume, cc/g	0.85	1.0
Effective Size, mm	0.8-0.9	0.75-0.90
Uniformity Coefficient	1.9 or less	1.9 or less
Mean Particle Diameter, mm	1.6	1.5
Pittsburgh Abrasion Number	70-80	50-60
NBS Abrasion No., % Retention/mm	70-75	74-82
Moisture as Packed, max.	2%	9%
Molasses RE (Relative Efficiency)	40-60	100-120
Ash	5-8%	12-18%
Mean Pore Radius	14 Å	33 Å

TABLE 4 TYPICAL PROPERTIES OF 12 x 40 MESH LIGNITE AND BITUMINOUS COAL CARBONS

	12 x 40 Mesh	
	Bituminous Coal Carbons (17, 18, 19)	Lignite Carbons
Total Surface Area (N_2 BET method) m^2/g	1000-1200	550-700
Iodine Number, min.	1050	550
Bulk Density, lbs./ft.^{3} Backwashed and Drained	25	23
Particle Density Wetted in Water, g/cc	1.3-1.4	1.3-1.4
Pore Volume, cc/g	0.94	1.0
Effective Size, mm	0.55-0.65	0.55-0.65
Uniformity Coefficient	1.9 or less	1.9 or less
Mean Particle Diameter, mm	1.0	0.85
Pittsburgh Abrasion Number	70-80	50-60
NBS Abrasion Number	70-75	74-82
Moisture as Packed, max.	2%	9%
Molasses Number	200-230	450-500
Ash	5-8%	12-18%
Mean Pore Radius	14 Å	31 Å

EPA-287 (Cin.)
(4-76)

Pittsburgh Chemical Company, Activated Carbon Division report in their literature that to adsorb color bodies and high molecular weight impurities, pores ranging from 20 to 500 A° are required (8).

Adsorption Data Developed on Various Types of Industrial Wastes

It follows that when treating waste streams containing pollutants with predominately large molecules, the lignite carbon should perform best. That is, the carbon dosage (lbs. of carbon required to treat a given volume of wastewater) should be less. The lignite carbon should load higher (remove more lbs. of impurity per lb. of carbon applied) and should remain in service for a longer period of time while producing a suitable effluent.

Tables 5 and 6 show comparative data from studies conducted on industrial waste streams containing predominately large molecules. The lignite carbon performed better than the bituminous coal carbon on an equivalent volume basis.

In the same token, when treating a wastestream containing pollutants with predominately small molecules, virgin bituminous coal carbon should perform best.

Figures 1 and 2 show comparative adsorption data from a study conducted by an east coast dye manufacturer (9). Isotherms were run comparing pulverized versions of virgin 12 x 40 mesh lignite and bituminous coal carbons. The dyes used in this study ranged in molecular weight from 350 to 1,370.

The bituminous coal carbon performed better than the lignite carbon with respect to dye removal and loading on the low molecular weight dyes. However, as the molecular weight (hence, molecular size) increased, the performance of the lignite carbon became better than that of the bituminous coal carbon. A summary of the results are:

Dye Molecular Weight	% Dye Removal*		Loading**	
	Lignite Carbon	Coal Carbon	Lignite Carbon	Coal Carbon
350	93	99	.21	.40
700	61	40	.10	.07
810	68	50	.17	.11
890	42	23	.08	.04
1370	65	38	.13	.08

*At a pulverized carbon dosage of 5,000 ppm.
**Lbs. of dye removed/lb. of carbon applied at 50% color removal.

Effect of Thermal Regeneration on the Adsorption Performance of Carbon

When granular activated carbon is reactivated, the internal pore structure of the carbon is altered. Surface area in the small pore (micropore) range is drastically reduced, and transitional pore surface area is increased slightly. Reasons for this phenomena are well documented (10, 11, 12).

TABLE 5 COMPARATIVE ADSORPTION DATA FROM A STUDY CONDUCTED ON AN EAST COAST DYE WASTE

A column study was conducted on a dye waste from an East Coast dye manufacturing and processing company. The waste was sand filtered and then fed to two sets of three 1-1/2" I.D. columns operated in parallel at a linear flow rate of 0.52 gpm/ft.^{2} Each set of three columns was then operated downflow in series. Empty bed contact time was 88 minutes through each set of three columns. One set contained an 8 x 35 mesh lignite carbon and the other contained an 8 x 30 mesh bituminous coal carbon.

	Lignite Carbon	Bituminous Coal Carbon
Avg. feed color, absorbance at 525 mμ wave length	1.123	1.123
Effluent color, absorbance at 525 mμ wave length (60% color removal)	0.449	0.449
Time it took for carbon to breakthrough (in hours)	197	69
Carbon dosage required, lb./1,000 gals.*	25.4	83.4

* These are the calculated dosages at 60% removal; dosages would be significantly lower in a countercurrent system.

EPA-287 (Cin.)
(4-76)

TABLE 6 COMPARATIVE ADSORPTION DATA FROM STUDIES CONDUCTED ON TWO DIFFERENT EAST COAST OIL REFINERY WASTES

Case 1. A column study was performed on sand filtered, API separator effluent from an East Coast oil refinery. Two sets of three 1-1/2" I.D. carbon columns were operated in parallel at a linear flow rate of 2 gpm/ft.^{2} Empty bed contact time was 18 minutes through each set of three columns. Each set of three columns was then operated upflow in series. One set contained a 12 x 40 mesh lignite carbon, and the other set contained a 12 x 40 mesh bituminous coal carbon.

	Lignite Carbon	Bituminous Coal Carbon
Avg. feed COD to carbon columns, ppm	104	104
Effluent COD from carbon columns*, ppm	31	31
Carbon Dosage, lb./1,000 gals.	0.93	1.31
Loading on carbon, lb. COD removed/lb. of carbon	0.65	0.46

Case 2. A column study was performed on sand filtered, API separator effluent from another East Coast oil refinery. Two sets of four 1-1/2" I.D. carbon columns were operated in parallel at a linear flow rate of 0.5 gpm/ft.^{2} Each set of four columns was then operated downflow in series. Empty bed contact time was 88 minutes through each set of four columns. One set contained an 8 x 30 mesh lignite carbon, and the other set contained an 8 x 30 mesh bituminous coal carbon.

	Lignite Carbon	Bituminous Coal Carbon
Avg. feed COD to carbon columns, ppm	70	70
Effluent COD from carbon columns*, ppm	21	21
Carbon dosage, lb./1,000 gals.	1.91	2.49
Loading on carbon, lb. COD removed/lb. of carbon	0.21	0.16

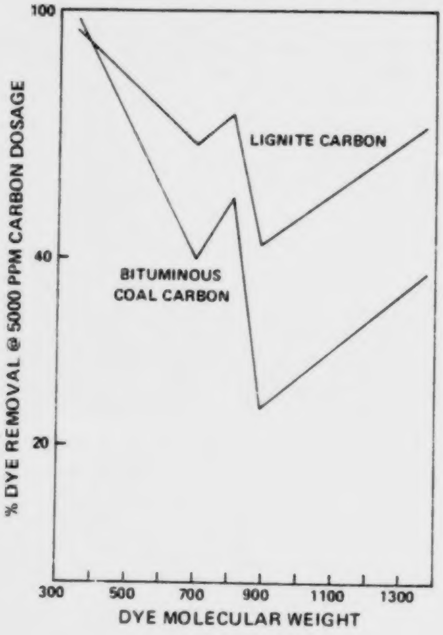
*Breakthrough at 70% removal.

EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

FIGURE 1

RELATIONSHIP BETWEEN DYE MOLECULAR WEIGHT AND % DYE REMOVAL AT A CARBON DOSAGE OF 5000 PPM



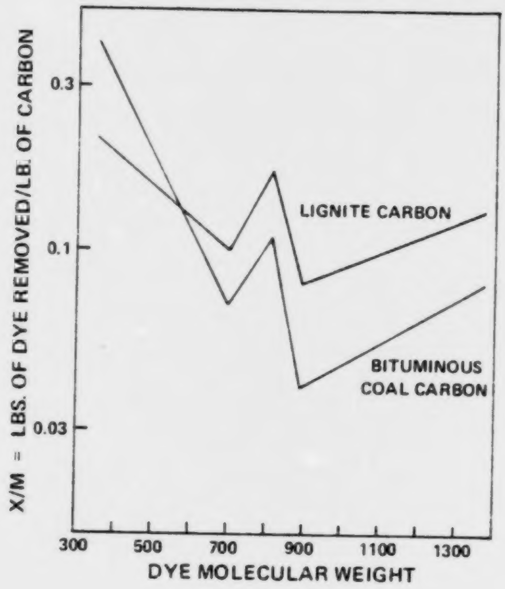
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD, BEGIN SECTIONS HERE

FIGURE 2

RELATIONSHIP BETWEEN DYE MOLECULAR WEIGHT AND CARBON LOADING @ 50% DYE REMOVAL



BEGIN LAST LINE OF TEXT
3/8"
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

The significance of this change in pore structure is that the adsorptive performance of a regenerated carbon can change drastically. The degree of change will depend on the nature of the organics to be adsorbed. If the organics are relatively large molecules, the performance of the reactivated carbon should be equal to or better than that of the virgin carbon. However, if the organics are relatively small molecules, the performance of the regenerated carbon will decrease substantially.

The reasons are:

- Large molecules are adsorbed in the transitional pores which are essentially unaffected in the thermal regeneration process.
- Small molecules are adsorbed in the micropores, a good portion of which are lost during reactivation.

Table 7 shows data developed at an east coast dye manufacturing plant (9). Isotherms were run with a virgin and a regenerated bituminous coal carbon using different molecular weight dyes. The performance of the reactivated carbon, as compared to its virgin counterpart, decreased considerably with the low molecular weight dye; but as the molecular weight of the dye (hence, molecular size) increased, the regenerated carbon performance was essentially the same as its virgin carbon counterpart.

Another east coast dye manufacturer, prior to conducting a column study, ran isotherms with pulverized samples of virgin 12 x 40 mesh lignite and bituminous coal carbons. The carbons in the column were exhausted and regenerated. Isotherms were then run on pulverized samples of the reactivated carbons. Figure 3 shows the isotherms (9).

The virgin bituminous coal carbon performed better than the virgin lignite carbon. This indicates that the waste contained predominately small molecules. The performance of the regenerated lignite carbon with respect to its virgin counterpart was essentially unchanged. The performance of the regenerated bituminous coal carbon was significantly poorer than its virgin carbon counterpart.

Although the virgin bituminous coal carbon performed better than the virgin lignite carbon at all dosage levels, the regenerated lignite carbon performed better than the regenerated bituminous coal carbon at the low carbon dosages.

The implications are:

- If the wastestream contains predominantly small molecules (this can be determined by comparing the relative performance of lignite and bituminous coal carbons on the same waste), data developed using regenerated carbon should be used to design the granular carbon system. Otherwise, the system can very easily be undersized.

  If regenerated carbon is not available, the system should be designed from data developed using a virgin lignite carbon. The reason is

TABLE 7 ISOTHERM STUDY DONE BY AN EAST COAST DYE MANUFACTURER COMPARING THE PERFORMANCE OF A VIRGIN AND REGENERATED BITUMINOUS COAL CARBON

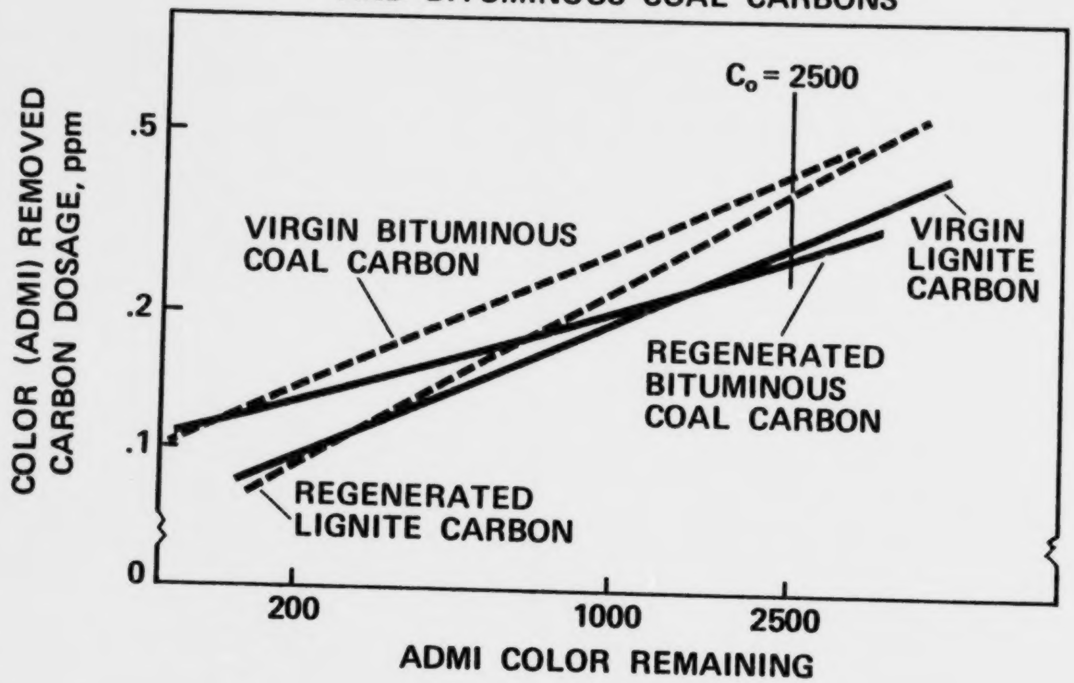
Dye Molecular Weight	Powdered Carbon Dosage, ppm	% Dye Removed*	
		Virgin Bituminous Coal Carbon	Regenerated Bituminous Coal Carbon
350	2000**	86	61
810	6000	44	41
1370	6000	26	29

* Initial dye concentration, 1000 ppm.

** 100% dye removed by both carbons at 6000 ppm dosage.

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

Figure 3
COMPARATIVE ADSORPTION ISOTHERMS ON VIRGIN AND REGENERATED LIGNITE AND BITUMINOUS COAL CARBONS



BEGIN LAST LINE OF TEXT
3/8"
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

because regenerated lignite carbon performance is similar to virgin lignite performance in wastestreams of this type.

- If the wastestream contains predominantly large molecules, the system can be designed based on the virgin carbon data; because the performance of the regenerated carbon will be at least as good as that of the virgin carbon.

Symbiosis

Utilization of the Carbon Fines in Other Wastewater Processes

When any granular activated carbon is transported and regenerated, the carbon will attrite to a certain degree and carbon fines will be created. These carbon fines are in essence powdered activated carbon.

It is well known that powdered activated carbon will improve treatment in activated sludge and anaerobic digestion systems (13, 14, 15, 16).

A daily influent powdered carbon dosage of about 15-50 ppm to an activated sludge system will improve plant operations by:

- Increasing BOD, COD, and TOC removals despite hydraulic and organic overloads.
- Aiding in solids settling, decreasing effluent solids and yielding thicker sludges.
- Adsorbing dyes and toxic components that are either not treated biologically or are poisonous to the biological system.
- Reducing aerator and effluent foam by adsorption of detergents.
- Preventing sludge bulking over broader F/M ranges.
- Improving nitrogen removal.
- Giving more uniform plant operation and effluent quality, especially during periods of widely varying organic or hydraulic loads.

A daily influent powdered carbon dosage of about 5-10 ppm to an anaerobic digester will:

- Improve supernatant quality thus reducing the load placed on the hydraulic part of the plant by decreasing fine solids recirculation.

- Increase digester gas production by catalyzing the destruction of volatile solids.

- Decrease the volume of volatile solids that a plant has to handle because of the increased destruction of these volatile filter operations.

- Improve the dewaterability of the inert solids drawn from the bottom of the digester. This will result in improved filter operations.

Carbon fines in a granular carbon system usually appear in backwash and overflow waters, and in the wet scrubber or dust collector of the

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD, BEGIN SECTIONS HERE

regeneration system. Usually, these fines are recirculated to the front end of the plant and are settled out in the primary clarifier. Or, the fines collected in the dust collector are disposed of with other plant sludges.

It would appear that one could take these fines and add them directly to the aerator of an activated sludge unit.

The fines should improve the quality of the activated sludge effluent. This would mean that the organic load to the granular carbon system would be lightened. This should result in lower carbon usage rates as well as an improvement in overall plant performance. Or, one could add the fines to any unit where carbon will end up in an anaerobic digester (e.g., a thickener).

Utilization of the Heat Content of the Exit Gases in Other Plant Processes

The furnaces used to regenerate granular activated carbon usually are equipped with an afterburner. Gases exiting the afterburner are generally at temperatures of 1,200°-1,400°F. These gases are normally vented to the atmosphere or passed through a wet scrubber.

6-1/2"

When the flue gas is vented, it would appear that the heat content of these gases could be used elsewhere in the plant. For example, one could take these gases and pass them through a waste heat boiler or a heat exchanger. Where applicable, process streams could be heated up by these gases, and one could defray some of the costs associated with steam generation.

Summary and Conclusions

In summary,

- Isotherms should be used to determine if carbon can reduce the impurity level to the desired quantity.

- Running comparative isotherms between lignite and bituminous coal carbons will give a good indication of the relative size of the pollutant molecules in a given waste. If the isotherms show the virgin lignite carbon to be best, the stream contains predominately large molecules. This means that breakthrough will occur when the transitional pore surface area becomes exhausted. If the opposite is true, the waste contains predominately small molecules. This means that breakthrough will occur when the micropore surface area becomes exhausted.

- Granular carbon systems should be designed on data developed from column studies--not isotherms.

- Lignite carbons perform better than bituminous coal carbons in wastestreams containing predominately large molecules.

- Virgin bituminous coal carbons perform better than virgin lignite carbon in wastestreams containing predominately small molecules. However, once either carbon is regenerated, surface area in the small pore range is

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

lost. After about 5-6 regenerations, the performance of both carbon types should be equivalent in waste streams of this sort.

If the wastestream contains predominately small molecules, the granular carbon system should be designed on the basis of the performance of regenerated carbon. If regenerated carbon is not available, the lignite carbon should be used to obtain the design parameters. The reason being that lignite carbon properties do not change as much as bituminous coal carbon properties upon regeneration.

Using the fines generated by transporting and regenerating granular activated carbon in either an activated sludge or an anaerobic digestion process may be feasible.

The heat value of the exit gases from a carbon regeneration furnace might find use in other plant processes.

REFERENCES

1. Keinath, T. M., "Design and Operation of Activated Carbon Adsorbers Used for Industrial Wastewater Decontamination," presented at the 68th Annual Meeting of American Institute of Chemical Engineers, Los Angeles, California, Nov. 19, 1975.

2. Hutchins, Roy A., "New Method Simplifies Design of...Activated Carbon Systems," *Chemical Engineering*, August 20, 1973.

3. Anon., "Adsorption Isotherm of Granular Carbon for Wastewater," PC-2, ICI United States Inc., Wilmington, Delaware.

4. Anon., "Evaluation of Granular Activated Carbon in Columns for Wastewater Treatment," PC-3, ICI United States Inc., Wilmington, Delaware.

5. Smisek, M. and S. Cerny, "Active Carbon," pp. 56-57, American Elsevier Publishing Company, New York, 1970.

6. Brunauer, S., P. H. Emmett and E. Teller, *Journal American Chemical Society*, 60, 309, 1938.

7. Abram, J. C., "The Characteristics of Activated Carbon," presented at Water Research Association Conference, University of Reading, England, April 3-5, 1973.

8. Anon., Product Data Bulletin, Pittsburgh Type SGL Granular Carbon, Pittsburgh Chemical Company, Activated Carbon Div., Pittsburgh, Pennsylvania.

9. DeJohn, Paschal B. and Hutchins, Roy A., "Treatment of Dye Wastes with Granular Activated Carbon," presented at The National Technical Conference of the American Association of Textile Chemists and Colorists, Chicago, Illinois, Oct. 15-17, 1975.

10. DeJohn, Paschal B., "Factors To Consider When Selecting Granular Activated Carbon for Wastewater Treatment," presented at the 29th Purdue Industrial Waste Conference, Purdue University, West Lafayette, Indiana, May 7-9, 1974.

11. Hutchins, Roy A., "Economic Factors in Granular Carbon Thermal Regeneration," Chemical Engineering Progress, November, 1973.

12. DeJohn, Paschal B., "Carbon From Lignite or Coal: Which is Better?", Chemical Engineering, April, 1974.

13. Adams, Alan D., "Powdered Carbon: Is It Really that Good?", Water & Wastes Engineering, March, 1974.

14. Clapp, Kenneth Edward, "Granular To Powdered Activated Carbon in Polluted Water Purification Process," United States Patent, October 23, 1973.

15. DeJohn, Paschal B. and Adams, Alan., "Activated Carbon Improves Wastewater Treatment," Hydrocarbon Processing, October, 1975.

16. Adams, Alan D., "Activated Carbon: Old Solution to Old Problem," Water & Sewage Works, August and September, 1975.

17. Internal ICI United States Inc. report, "Competitive Carbon Study."

18. Anon., Calgon Activated Carbon Product Bulletin 20-2C, Filtrasorb 300 and 400 for Wastewater Treatment, Calgon Corporation, Pittsburgh, Pennsylvania, 1970.

19. Anon., Product Data Bulletin, Nuchar Granular Active Carbon, Grade: Nuchar WV-L 8 x 30, West Virginia Pulp and Paper, Covington, Virginia.

20. Anon., Product Data Bulletin, Nuchar Granular Active Carbon, Grade: Nuchar WV-G 12 x 40, West Virginia Pulp and Paper, Covington, Virginia.

PB83-142232

FULL SCALE EXPERIENCE WITH ACTIVATED CARBON TREATMENT OF JOINT MUNICIPAL - INDUSTRIAL WASTEWATER

J. L. Taylor
City of Fitchburg
Wastewater Treatment Facilities
Lanides Lane, Fitchburg, Massachusetts 01420

ABSTRACT

In the late 1960's, Fitchburg, like many communities, found itself faced with a serious water pollution problem. An engineering firm was hired to recommend and design a solution to the problem. Their recommendation resulted in the construction of two (2) new advanced Wastewater Treatment Facilities. One of these facilities, the West plant, is a physical-chemical plant designed mainly to service the area's paper manufacturing facilities. Since plant startup, in mid 1975, numerous mechanical and process difficulties have occurred. The plant has operated in a continuous mode for only a relatively short period of time. Experiences at Fitchburg as well as other physical-chemical treatment plants have made certain factors obvious. It has also shown that numerous questions remain to be answered.

TEXT

In the early 1960's, pressure began building concerning the quality of Massachusetts Waterways. Fitchburg, being a heavily industrialized city, was directly affected by this pressure.

Fitchburg is located at the headwaters of the north branch of the Nashua River. Flow in this stream varies dramatically on a seasonal basis. Usually the dry weather flow is about 10% of the wet weather flow and under draught conditions, almost the entire flow through the City of Fitchburg is paper mill effluent.

The City commissioned an engineering firm in 1967 to study its pollution problems and recommend a course of action. The firm recommended abandoning the City's existing trickling filter plant and constructing two new Wastewater Treatment Facilities. One of these facilities, the East plant, would replace the old trickling filter plant and serve the majority of residential and commercial properties. The other would be located in West Fitchburg and primarily service the area paper mills. About 10% of the plant flow was anticipated to be domestic sewage.

Fitchburg's paper mills are speciality grade production facilities. The majority of the paper manufactured is either colored or chemically treated with silicones, latexes or starches.

The original facility design recommendation for handling the paper mill waste in West Fitchburg was an activated sludge plant. Later, the design recommendation was changed to an activated carbon facility for the following reasons:

1. The extreme fluctuations in wastewater characteristics discharged from the industries making it extremely difficult to maintain a high quality effluent from a biological system.

2. The belief that the activated carbon process would be better able to meet more stringent discharge standards so future plant upgrading would not be necessary.

3. The uncertainty of the color removal capabilities of a biological treatment system.

The West Fitchburg Wastewater Treatment Facility is one of two advanced Waste Treatment Plants which were started up by the City in the latter half of 1975. The plant is designed for 15 MGD and normally averages eleven (11) to thirteen (13) MGD. Of that flow, roughly two (2) percent is of domestic origin. The domestic waste receives primary settling and chlorination prior to being mixed with the main inflow stream. The majority of the influent is generated at the area paper production facilities. A total of five (5) production facilities, plus a central power plant, discharge their wastewater to the West plant.

The treatment plant processes include chemical coagulation utilizing alum, lime and polyelectrolytes, flocculation, settling, and then filtration through activated carbon units. The effluent is aerated prior to discharge at the headwaters of the North Nashua River. Solids handling facilities consist of gravity thickening followed by earthen dewatering lagoons and land burial. The plant does have facilities for onsite thermal reactivation of the activated carbon. The 12 downflow pressure carbon filters are backwashed daily with filtrate. Hydraulic transferring of the carbon and other plant water usages are also supplied from the filter effluent.

The plant was designed to produce an effluent quality of 8 MS/L for both BOD_5 and TSS on a monthly average. The cost of operating and maintaining the facility is shared by all users and is apportioned based on the flow, suspended solids and organic loadings.

Full plant operation has been limited due to a series of mechanical and process difficulties. The first major setback was with the primary sludge pumping system. Complete system modification took over a year, but a temporary installation allowed the facility to operate receiving partial flow until a permanent solution was developed. During this interim period, work started on debugging the activated carbon system. Soon after starting the carbon filtration system, one of the filter units exceeded its pressure rating which caused the protective relief valve to open. The drain pipe receiving this flow had been buried with a temporary plug at one location and subsequently, a section of the floor slab was lifted until it cracked and relieved the pressure. As a result, the buried line was abandoned and replaced with a new pipe above the floor slab.

As run time of the carbon filters accumulated, the generation of Hydrogen Sulfide within the carbon columns became apparent. The most successful method of controlling H_2S generation at that time according to EPA was by feeding a nitrate solution. Nitrates are preferred by anaerobic bacteria over sulfates as an oxygen source and nitrogen gas is produced instead of sulfide gas. The annual cost of feeding nitrates in our waste stream was projected to be in the order of $140,000 - $200,000.

This represented a ten (10) to fifteen (15) percent increase in projected annual operating cost, thus necessitating a search for an alternative odor control method.

Our thoughts centered around a toxicity approach, yet it had something easily handled and environmentally safe to dispose of. A literature survey indicated that an alkaline environment could inhibit metabolism enough to act effectively as a disinfectant. Laboratory studies were undertaken to verify that sulfide producing bacteria could be destroyed by exposure to a pH related environment. When this hypothesis was proven correct, work was expanded to develop time/pH/effectiveness information. These results demonstrated that contacting sulfur reducing bacteria for twenty-four (24) hours at a pH greater than 11.5 would result in zero bacteria recovery. Full scale evaluation of this method was initiated in the Fall of 1976. Initial results demonstrated the growth rate of the bacteria removed during the filtering process would require a disinfection procedure once every five (5) or six (6) weeks to effectively control sulfide odors. This would have resulted in a chemical expense of about $20,000 annually. However, since biological growth is related to temperature, we estimated the average disinfection frequency required to be twice that of the winter months or an annual cost of $40,000. As we got into the summer months we found it increasingly difficult to achieve satisfactory disinfection and realized something else would have to be done to control sulfide odors during the warm weather period.

A modification to the system was attempted in the summer of 1978. Biological activity was allowed to occur in the filter vessels,but the filter effluent pH was elevated to 8.5 to keep the sulfides in the soluble form. At this point the effluent was aerated to air oxidize the sulfide to sulfate.

This modification has proven to be cost effective and generally successful in controlling the sulfide odor. However, controlling the sulfide odor has unmasked another odor which currently is unidentified. The best description of this odor is a low tide or dead fish smell. This "dead fish" type odor emanates from the river for about 1/2 mile beyond the plant discharge. The odor essentially disappears when the carbon system is bypassed.

Other major failures in the carbon adsorption system have included surface wash shower mechanisms breaking, a pipe coupling separating on the discharge side of one of our main filter dosing pumps, inability of an automatic flow control system to properly control the flow distribution between the individual filter units and corrosion of the filter vessels due to an apparent problem with filter liners. The failure of surface washing mechanisms and corrosion of filter vessels have been reported at various other activated carbon facilities.

The carbon regeneration system has only operated on an intermittent basis to date. Major problems exist with carbon feed control to the reactivation furnace, excessive pump wear when moving the carbon slurry and carbon losses within the system. Reactivated carbon quality appears to be most sensitive to the spent carbon quality and the contact time of the carbon in the reactivation zone. Steam feed and reactivation zone temperature do play a part in controlling the reactivated carbon quality, but are only effective in optimizing or fine tuning process efficiency.

Aside from the many equipment problems at the plant, the overriding major difficulty of the facility to date has been its inability to produce an effluent quality which satisfies discharge permit limitations. Even though we have been able to pass the total plant flow through the adsorption system for a relatively short period, it has been evident that the effluent quality would exceed the allowable BOD$_5$ discharge for quite some time. The City is currently under an EPA administrative order to proceed with a 201 Facilities Plan to bring the plant into compliance with discharge permit requirements. A Step 1 Grant application is being prepared so engineering work to bring about compliance may proceed. In addition, the City is seeking to recoup damages through litigation.

A significant effort has been put forth in developing sampling and monitoring procedures that accurately reflect unit process performance. The major factor influencing operating cost of an activated carbon treatment system is reactivation frequency. Regenerating the carbon too frequently increases utility and fuel consumption costs and results in excessive makeup carbon purchase to replace the carbon lost during the reactivation process. However, utilizing the carbon beyond a certain point makes effective reactivation extremely difficult. Currently, the operating and maintenance cost for the West Fitchburg Facility is about $375 per million gallons.

Carbon facilities treating a multiple component waste stream have not observed removal efficiencies that approach the typical "S" type curve presented in the literature. This makes the determination of when to reactivate carbon extremely subjective. Data generated to date on the carbon filter BOD$_5$ reduction has shown some significant trends. The first thing we consistently observe is a very high removal efficiency for the first seven (7) to fourteen (14) days of operation with either virgin or reactivated carbon. The removal efficiency in this time frame is in excess of 75%. The second observation is a transition period of varying removal efficiencies which quickly levels out at around a 60% efficiency. From this transition period only a very gradual loss in removal efficiency is experienced, even when the carbon has been loaded beyond what is normally accepted as exhausted. We have measured BOD$_5$ removal efficiencies of better than 50% when the carbon it was applied to had an iodine value of less than 400. Generally, an iodine number lower than 550 is considered to indicate exhaustion.

Figure 1 is a plot removal efficiency vs. run time for a typical filter unit at the Fitchburg Facility. The 340 million gallons treated represents over 6 months of operation without reactivation. The carbon has adsorbed over .5# of BOD_5 per pound of carbon. Figure 2 is a graph of the filter effluent BOD_5 from the same unit over the same time period. Removal efficiency does show some positive correlation with the applied load which tends to dampen fluctuations in the effluent quality. However, the effluent quality also exhibits random fluctuations indicative of changes in the characteristics of the influent organic load.

A number of hypotheses have been developed based on our observations to date, some of which have been verified and implemented to improve plant performance and reliability. Others require careful evaluation under controlled conditions. For example, our system utilizes the activated carbon as a filter media as well as an organic adsorber. This necessitates daily backwashing of the media and results in mixing the contents of the bed. Although theoretically the bed should resettle according to particle size, the carbon particle density has been altered somewhat by adsorbing organic material. This raises the question of whether particle size controls the stratification as in a sand filter, or particle density as in a mixed media filter. This question is extremely important when a design is based on the traditional wave theory of exhaustion.

Recent articles have reported measurements which demonstrate that selective desorption occurs in water treatment plants where carbon is utilized for taste and odor control. It seems reasonable to assume that the same phenomena exists in wastewater plants using activated carbon. The impact of desorption of effluent BOD_5 and COD should be evaluated in light of the current discharge permit program where BOD_5 is generally used to determine organic strength.

Consideration should also be given to the use of pH control to optimize carbon adsorption efficiency, particularly on waste streams that exhibit very consistent characteristics.

One topic that is currently receiving considerable attention is the effect of bioactivity on process efficiency. Literature cites greatly enhanced carbon adsorptive capacity due to biological activity consuming organic material adsorbed on activated carbon. This, in effect, would continuously release adsorption sites for further adsorption. Electron microscope photographs, however, show numerous bacteria present during bioactivity that are about the same diameter as many surface pores as well as a significant amount of slime that could block adsorption sites and possibly hinder adsorption. Two Wastewater Treatment Facilities utilizing carbon adsorption have observed at least temporary increases in carbon removal efficiency immediately following a procedure that effectively destroyed biological activity.

During studies on the effectiveness of an alkaline soak for sulfide control, parallel pilot columns were operated for a three-month period. One column was fed nitrates, one was periodically dosed and soaked with caustic, and in a third column bacterial action was allowed to occur producing sulfides. BOD_5 removal efficiency for the three columns showed no statistically significant variation. We are currently conducting studies to compare the possible long term benefits of biologically active carbon with the potential surface adsorption interference due to biological slime growth. Our experiences to date have led us to believe that any increase in process efficiency due to biological activity is negligible.

In addition, numerous secondary effects are observed which must be considered in the overall cost benefit analysis. These include increased headloss resulting in higher pumping costs, and corrosion of electrical gear due to the presence of sulfides.

The chemical primary system has performed extremely well since initial startup, the process has consistently yielded a 55% BOD_5 reduction, 95% suspended solids removal and 95% turbidity reduction. The carbon system has provided an average 60% reduction of the remaining BOD_5 and about 70% of the remaining suspended solids. Overall plant efficiencies of 80% BOD_5 and 98% TSS have been sustained during normal operation.

Based on experiences to date at Fitchburg and a number of other physical chemical treatment facilities, I believe certain things have become evident:

1. Special consideration must be given to the physical and mechanical design problems associated with activated carbon storage and transport.

2. The conclusions drawn from previous work concerning activated carbon treatment technology must certainly be qualified based on factors that were, and were not, considered during those investigations.

3. Scale up from pilot studies to full scale must take into account more factors than just contact time and theoretical exhaustion rates.

4. Studies examining activated carbon treatment performance on a single or homogeneous waste stream are not directly correlatable to variable situations.

5. More knowledge must be generated on carbon adsorption kinetics before it should be considered a predictable technology.

As for the future of activated carbon adsorption as a unit treatment process, I envision the major application area to be removal of toxic organic compounds. I believe there are numerous other applications for activated carbon in wastewater treatment, but they are dictated by specific conditions and the carbon utilized for a limited role in the overall treatment scheme.

If carbon adsorption is to be considered in the future for a major role in wastewater treatment systems, major changes will be required in the way process evaluations and facility designs are conducted. Experience has shown that questions concerning activated carbon treatment still remain to be answered, and it will be the answers to these questions that determine the potential for the use of activated carbon in wastewater treatment in the future.

REFERENCES

1. "Process Design Manual for Carbon Adsorption." U.S. Environmental Protection Agency Technology Transfer, Washington, D.C., October, 1973.

2. Burt, N.E. and Taylor, J.L. "Hydrogen Sulfide Control in Activated Carbon Filters by Caustic Disinfection." Unpublished, 1976.

3. Callahan, W.F. "Summary Report on Activated Carbon Pilot Plant at the West Fitchburg Plant." Unpublished, 1977.

4. Directo, L.S., Chen, D. and Kugelman, I.J. "Pilot Plant Study of Physical-Chemical Treatment." Journal WPCF, October, 1977.

5. Dallaire, G. "Carbon Treatment of Drinking Water: N.J. Plant Trying to Get Out the Bugs." Civil Engineering, January, 1980.

6. Weber, W.J. et al. "Biological Growth on Activated Carbon: An Investigation by Scanning Electron Microscopy." Environmental Science and Technology, 12, 6 (1978).

7. Ying, W. and Weber, W.J. "Bio-Physiochemical Adsorption Model Systems for Wastewater Treatment." Journal WPCF, November, 1979.

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

WEST FITCHBURG WWTF

BOD$_5$ REMOVAL EFFICIENCY

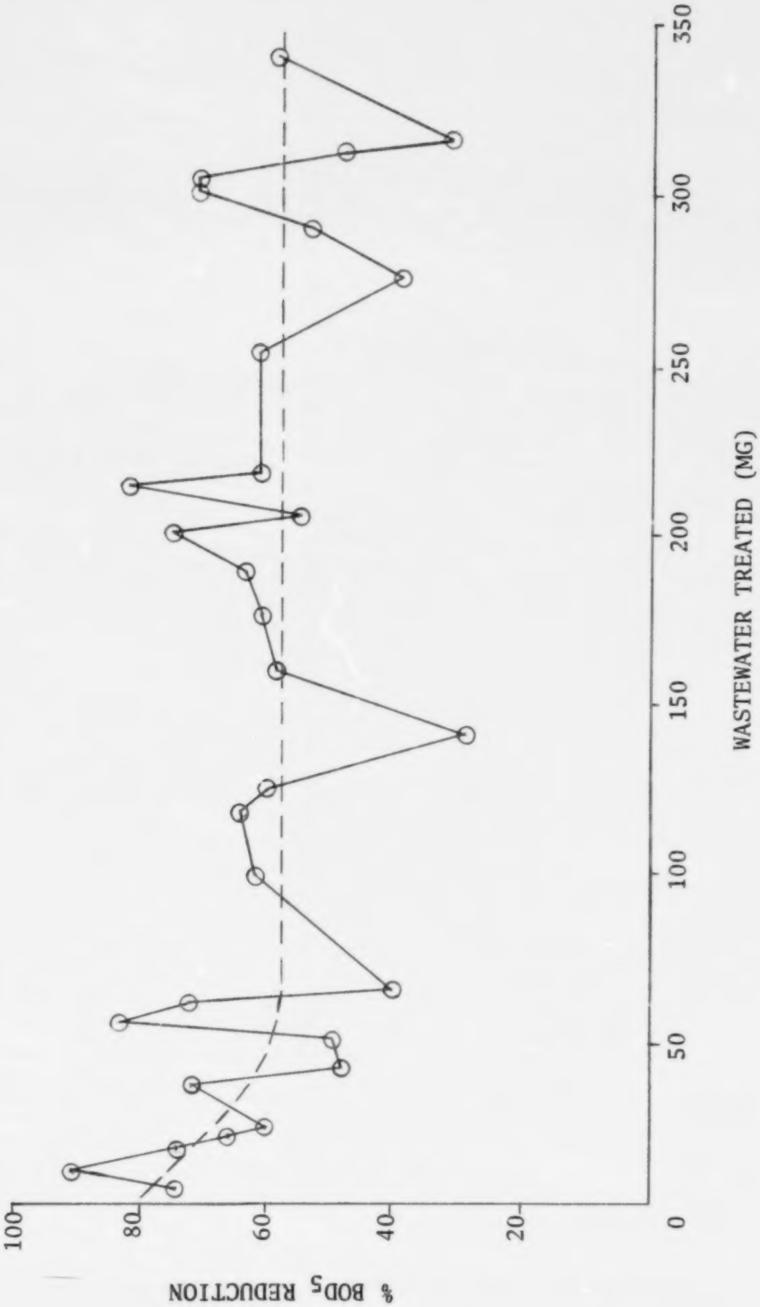


FIGURE 1

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

WEST FITCHBURG WWTF

CARBON FILTER EFFLUENT QUALITY

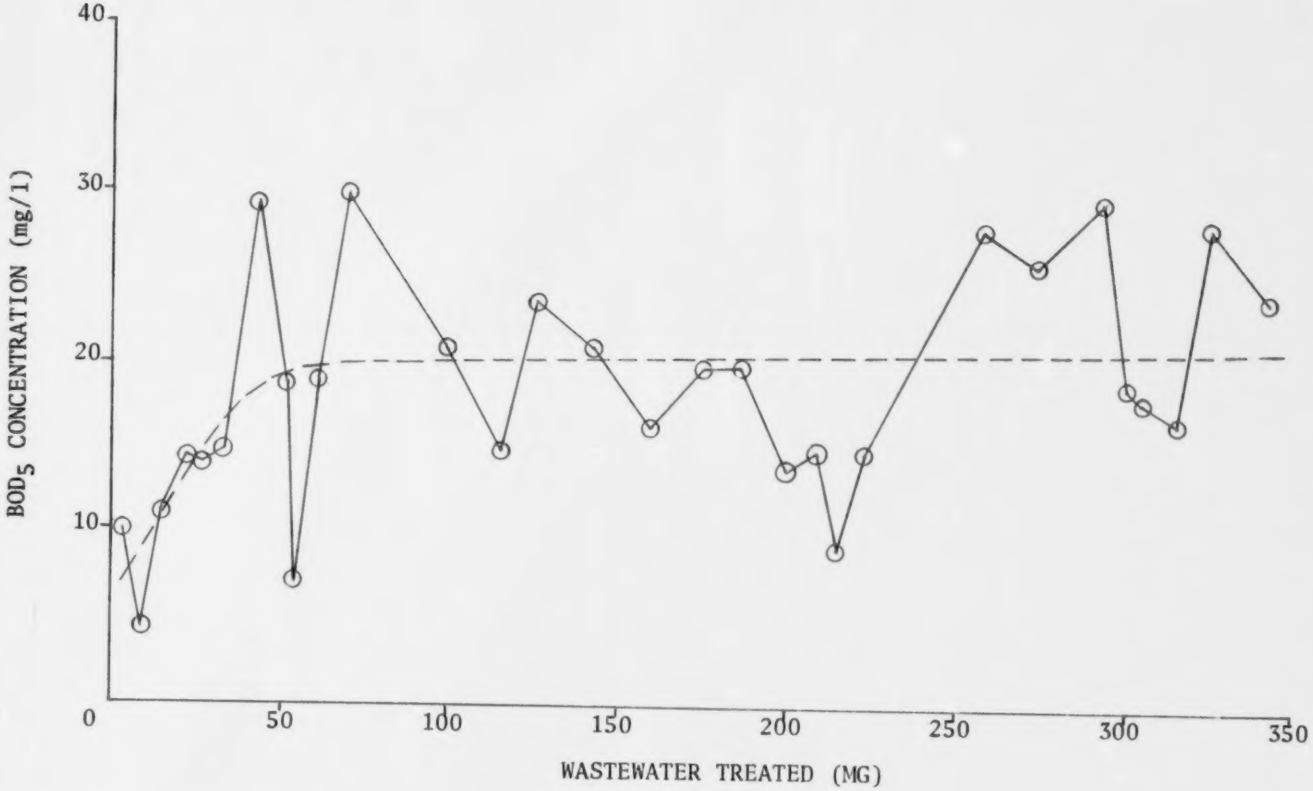


FIGURE 2

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
DROPPED HEAD, BEGIN SECTIONS HERE
CENTER OF PAGE
TOP OF IMAGE AREA
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
PAGE NUMBER
EPA-287 (Cin.)
(4-78)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

PB83-142240

TEXTILE WASTE TREATMENT AT A MUNICIPAL PACT* FACILITY

C. A. Pitkat, Superintendent
Water Pollution Control Facility
Vernon, Connecticut 06066

and

C. L. Berndt, Senior Systems Engineer
Zimpro Inc.
Rothschild, Wisconsin 54474

ABSTRACT

The first U.S. municipal Powdered Activated Carbon Treatment (PACT)* facility is currently in operation at Vernon, Connecticut. The PACT process is performing well treating a highly colored textile wastewater despite the treatment system and plant equipment problems that have occurred in the initial year of operation of the facility. Both a low effluent BOD$_5$ concentration (<5 mg/L) and efficient color removal have been maintained. This paper describes the initial year of PACT operation.

INTRODUCTION

This paper describes the initial operation of the 24,500 M^3/day (6.5 MGD) Powdered Activated Carbon Treatment (PACT) process located in the Town of Vernon, Connecticut. The municipal treatment facility at Vernon serves a residential population of approximately 30,000 people and an industrial fraction that consists of textile dyehouse operations, metal plating, and manufacturing industries.

Prior to 1978, wastewater treatment at Vernon consisted of primary settling, dual trickling filters, clarification and chlorination prior to discharge to the Hockanum River. Primary sludge solids and trickling filter humus were anaerobically digested, chemically conditioned and landfilled. Performance of the trickling filter plant was less than adequate due, in part, to the dyehouse wastes. BOD$_5$ and suspended solids removals averaged approximately 60 to 70%. Color removal was non-existent.

In addition to its poor performance, the trickling filter was operating near its design flow capacity.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
6-1/2"
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

Since the receiving stream, the Hockanum River, experiences extremely low flow periods during the summer, and the desired stream quality dictated that plant effluent BOD_5 levels be less than 20 mg/l with color discharges controlled, it became necessary to upgrade treatment at Vernon.

Though numerous treatment systems were considered for application at Vernon, the process selected and implemented was the PACT process - the use of powdered activated carbon in the aerator of the activated sludge process. When Zimpro Inc. Wet Air Oxidation is applied to the PACT process for spent carbon regeneration, the treatment is commonly referred to as the Wastewater Reclamation System (WRS) and is hereafter referred to as such.

DESCRIPTION OF SYSTEM

The treatment facility layout is shown in Figure 1, the treatment plant flow scheme in Figure 2. Details of the process design are listed in Table 1. Raw wastewater enters the treatment facility at the preliminary treatment area receiving coarse screening and comminution. Grit is then removed from the waste by two parallel aerated grit chambers, washed and transported to landfill. The raw wastewater is subsequently pumped to two 24.4 m diameter primary clariflocculators. Though not used to date, chemical coagulation is provided for suspended solids and pH control. Primary solids are pumped to two gravity thickeners located adjacent to the incineration building. Thickened primary sludge at 6% to 8% solids is chemically conditioned with ferric chloride and lime and dewatered to 25% solids on two rotary vacuum filters. The dewatered sludge, presently transported to landfill, is to be incinerated in a 7 hearth multiple hearth furnace.

From the primary clariflocculator, the settled wastewater flows to a 6 m (20 feet) square and 4.6m (15 feet) deep scrubbing channel where the regenerated carbon is added to the primary effluent wastewater flow. The flow is then split between 4 aeration tanks. To supply the biological oxygen requirements coarse bubble diffusers are located along one side of each aeration tank. Three 5,000 SCFM aeration blowers are provided and located within the regeneration building. All aeration tanks can be operated in a plug flow or complete mix mode. The aeration tanks and final clarifiers can also be operated in a two stage treatment mode.

Liquid cationic polymer is applied to the MLSS at each aeration tank outlet prior to flow to the final clarifiers. Thickened clarifier underflow from each final clarifier is removed by a rapid sludge pickup mechanism and recycled to the inlet of the aeration tanks.

Following solids separation, the clarified water is pumped to the four dual media filters located in the filtration building. The product water is disinfected and discharged to the Hockanum River. Optionally, the clarifier effluent can be passed directly to the chlorine contact chamber for disinfection and discharge.

The excess secondary sludge, a mixture of spent powdered activated carbon and biomass, is wasted from the recycle lines to the two spent carbon gravity thickeners which are located adjacent to the regeneration building.

EPA-287 (Cin.)
(4-76)

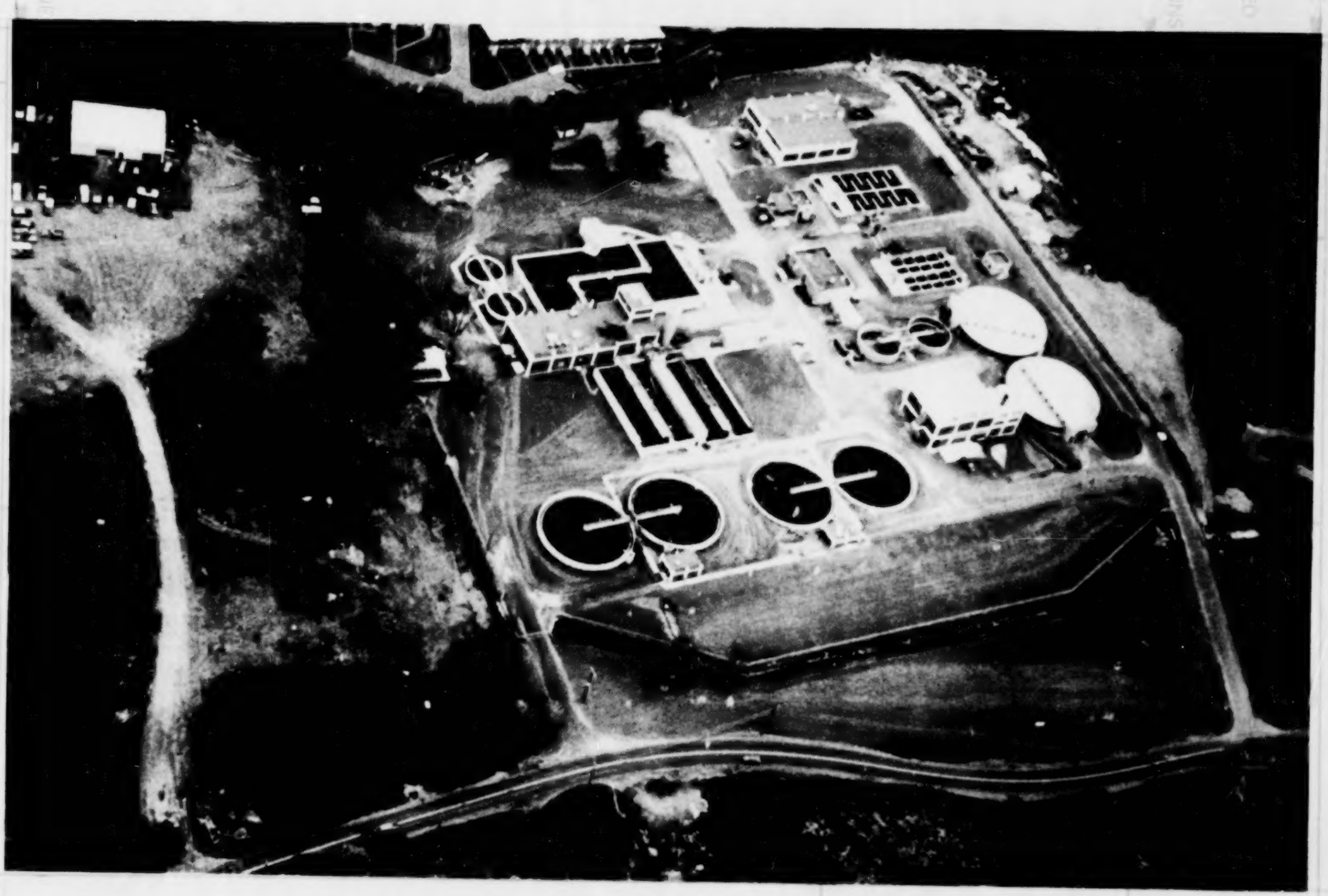


Figure 1. Wastewater Treatment Facility; Vernon, CT.

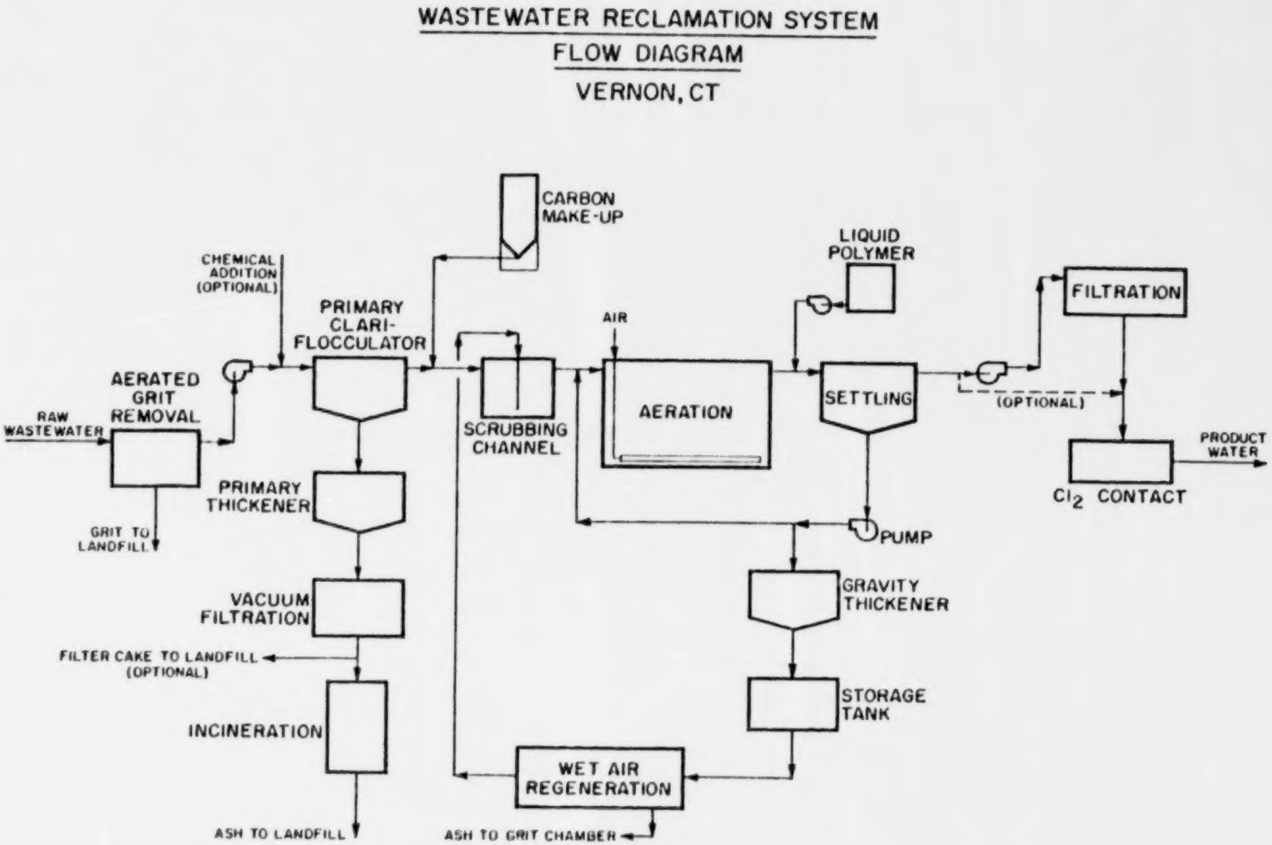

WASTEWATER RECLAMATION SYSTEM
FLOW DIAGRAM
VERNON, CT
RAW WASTEWATER
AERATED GRIT REMOVAL
GRIT TO LANDFILL
CHEMICAL ADDITION (OPTIONAL)
PRIMARY CLARI-FLOCCULATOR
PRIMARY THICKENER
VACUUM FILTRATION
FILTER CAKE TO LANDFILL (OPTIONAL)
INCINERATION
ASH TO LANDFILL
CARBON MAKE-UP
SCRUBBING CHANNEL
AIR
AERATION
LIQUID POLYMER
SETTLING
PUMP
GRAVITY THICKENER
STORAGE TANK
WET AIR REGENERATION
ASH TO GRIT CHAMBER
(OPTIONAL)
FILTRATION
Cl2 CONTACT
PRODUCT WATER

Figure 2. Flow Diagram of the Wastewater Treatment Facility; Vernon, CT.

TABLE 1 PROCESS DESIGN AND EQUIPMENT DATA; VERNON, CT.

Primary Clarifloculator Tanks	
Number	2
Size	24.4m X 24.4m (80 ft x 80 ft) 4.0m (12.75 ft) SWD
Overflow Rate @ Q average	1.35 m^3/m^2 /hr (800 gpd/ft^2)
Sludge Pumps	3 @ 57 m^3 /hr (250 gpm)
Aeration Tanks	
Number	4
Size	27.4m x 7.6m (90 ft x 25 ft) x 3.6m (12 ft) SWD
Detention @ Q average	3.0 hrs
MLSS Concentration	12,000 mg/L
Secondary Clarifiers	
Number	4 Centerfeed
Size	23m (75 ft) Diam x 4.0m (12.75 ft) SWD
Overflow Rate @ Q average	0.7 m^3/m^2/hr (400 gpd/ft^2)
Overflow Rate @ Q peak	1.9 m^3/m^2/hr (1075 gpd/ft^2)
Return Sludge Pumps	
Number	6 @ 360 m^3/hr (1600 gpm)
Dual Media Filters	
Number	4
Size	5m x 11.6m (16 ft x 38 ft)
Hydraulic Loading @ Q average	6.1 m^3/m^2 /hr (2.5 gpm)
Media	0.60mm sand and anthrafilt cap
Gravity Sludge Thickeners	
Spent Carbon, Number	2
Size	9.1m (30 ft) Dia x 4.0m (12.75 ft) SWD
Primary Sludge	
Number	2
Size	12.2m (40 ft) Dia x 4.0m (12.75 ft) SWD
Vacuum Filters	
Number	2
Filter Area, each	35m^2 (376 ft^2)
Solids Loading	1.7 Kg/m^2/hr (3.5 lb/ft^2/hr)
Incinerator	
Number	1
Size	5.1m (16 ft 9 in) O.D.
Hearths	7
Wet Air Regeneration Unit	
Number	1
Design Flow	3.15 L/sec (50 gpm)
Feed Solids Concentration	60 g/L
Design Temperature	240° C (470° F)
Design Pressure	63 Kg/cm^2 (900 psig)

Clarified overflow from the thickeners returns to the scrubbing channel. Thickener underflow is pumped to a 130 M^3 (4500 ft^3) mixed storage tank prior to regeneration to allow the WAR unit to operate relatively independent of the spent carbon thickeners.

The thickened carbon slurry is subjected to Wet Air Regeneration (WAR) to recover the activated carbon for reuse and destroy the associated organic solids. The WAR unit's flow scheme is shown in Figure 3. One of two high pressure pumps raises the spent carbon slurry to a pressure of approximately 56 Kg/cm^2 (800 psig), pumping the slurry into the heat exchangers. Each pump is a variable flow triplex piston pump sized to provide up to a 3.8 L/sec (60 gpm) flow.

Compressed air, provided by two of three process air compressors, is added to the carbon slurry flow prior to the heat exchangers. One process air compressor serves as a standby unit. The combined slurry and air mixture passes thru heat exchangers where its temperature is raised to the desired reactor inlet temperature of 195-205°C (380-400°F). In the system reactor the biological solids and sorbed organics contained in the slurry are wet oxidized. A net heat gain is realized by the oxidation reactions that take place. The small amount of solubilization of organics that does occur is returned to the aeration basins for biodegradation. Hot reactor products are passed through the heat exchangers to recover the produced heat. The cooled regenerated slurry is passed through a pressure reducing station and added to the wastewater flow at the scrubbing channel. The spent air from the WAR process is collected from the scrubbing channel and is treated prior to discharge.

Two steam generators are provided in the regeneration system for use in system start-up only.

WASTEWATER CHARACTERISTICS

The Vernon treatment facility was designed on the basis of the flow data and wastewater concentrations as shown in Table 2. The wastewater contains, besides typical domestic wastewater, industrial wastes from a synthetic textile processing facility. Other industrial wastes include those from the manufacture of electrical controls and equipment, manufacture of electrical components such as printed circuit boards, aluminum and foil anodizing, and wastewaters from the production of water and auto filters.

TABLE 2 DESIGN CRITERIA; VERNON, CT.

Daily Flow, M^3/Day	=	24,600 (6.5 MGD)
Peak Flow, M^3 /Day	=	66,300 (17.5 MGD)
Influent BOD_5, mg/L	=	150 to 300
Effluent BOD_5, mg/L	=	< 20
Influent SS, mg/L	=	150 to 400
Effluent SS, mg/L	=	< 10
Influent Color, APHA	=	50 to 600
Effluent Color, APHA	=	Colorless

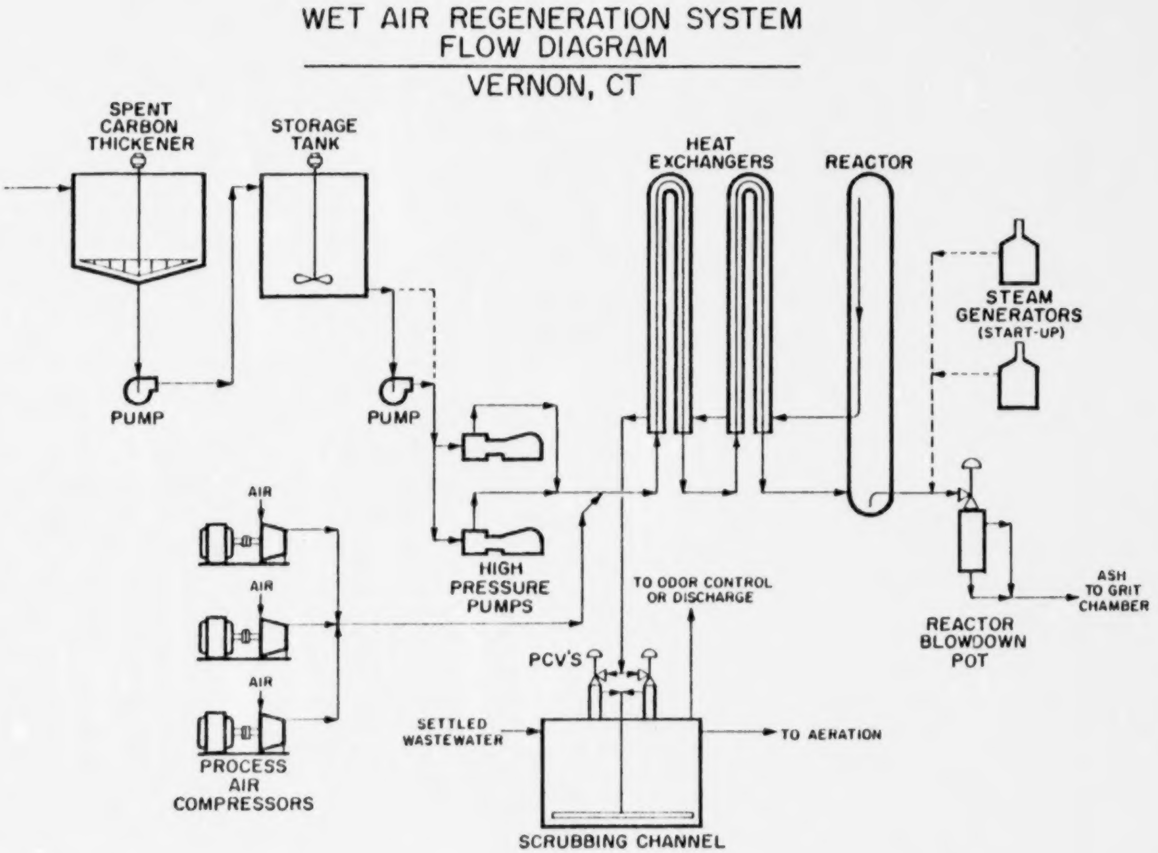

WET AIR REGENERATION SYSTEM
FLOW DIAGRAM
VERNON, CT
SPENT CARBON THICKENER
STORAGE TANK
HEAT EXCHANGERS
REACTOR
STEAM GENERATORS (START-UP)
PUMP
PUMP
HIGH PRESSURE PUMPS
AIR
AIR
AIR
PROCESS AIR COMPRESSORS
TO ODOR CONTROL OR DISCHARGE
PCV'S
SETTLED WASTEWATER
TO AERATION
SCRUBBING CHANNEL
REACTOR BLOWDOWN POT
ASH TO GRIT CHAMBER

Figure 3. Flow Diagram of the Wet Air Regeneration System; Vernon, CT.

The textile dyehouse operation is primarily engaged in nylon fabric dyeing and finishing with a much smaller emphasis on other synthetic fibers such as polyester, polyester cotton blends, acetate and cellulosic fabrics. Acid dye-stuffs at neutral pH levels are principally used for the nylon fabric processing along with various dyeing assistants and finishing chemicals. The principal acid dyestuffs include various orange, red, blue, navy and black dyes as listed in Table 3. Small amounts of disperse and direct dyestuffs are also used. Primary dyeing assistants and finishing chemicals used are presented in Table 4. The use of these dyes and finishing chemicals results in an alkaline wastewater with a significant BOD_5, high COD level and high color level. Much variability is noted in the waste since the product manufacture varies greatly.

TABLE 3 TYPICAL DYESTUFF

Nylanthrene Orange BGN
Nylanthrene Red B2B
Nylanthrene Navy LFWG
Altcofast Black N5X
Nylomine Blue AG
Supernylite Scarlet B

TABLE 4 DYEING ASSISTANTS AND FINISHES

Dyeing Assistants
Acetic Acid
Ammonia
Caustic Soda
Monosodium Phosphate
Trisodium Phosphate
Sodium Chloride
Xylol
Finishes
Zepel RN
Disodium Phosphate
Enegen (detergent)
Triamine (detergent)
Melamine Formaldehyde

Analysis of the other industrial wastes show that varous contaminants are present at high levels in specific wastes. Organic contaminants, ammonia nitrogen and COD, are present at high concentrations. Metals including aluminum, iron and particularly copper are present at very high concentrations in some industrial discharges. Other contaminants including cyanide, cadmium, nickel, zinc, and chromium are present at low levels. The industrial wastes all exhibit low BOD_5/COD ratio's indicative of the industrial nature of the wastes.

The Vernon treatment facility also receives raw septage on a five day/week basis. Approximately 120,000 to 150,000 gallons of septage per month are received on a Monday thru Friday basis and discharged directly to the

EPA-287 (Cin.)
(4-76)

plant influent sewer. A septage holding and metering facility is installed but has not operated as yet.

The influent pH levels to the Vernon facility vary from approximately six to ten. However, short-term raw waste pH fluctuations from three to twelve units have occasionally occurred. The effluent pH levels average approximately 7.0.

Wastewater Sampling and Analytical Procedures

Wastewater analytical data reported in this paper were performed according to Standard Methods and Zimpro Inc. analytical methods (1) (2). Adaptation of conventional analytical procedures have been made to accurately report the low carbonaceous BOD_5 and true color measurements obtained. The partitioning of the mixed liquor suspended solids into the volatile biomass and volatile activated carbon concentrations were obtained by a nitric acid digestion technique (2).

Wastewater sampling is conducted daily in accordance with the current regulatory requirements for the treatment facility.

TREATMENT SYSTEM OPERATION AS ACTIVATED SLUDGE

Primary Treatment

The primary treatment system was placed into service in July 1978. Performance indicated that 50 percent suspended solids removal from the raw wastewater could be expected without chemical addition. Though testing with ferric chloride up to application levels of 80 mg/L as $FeCl_3$ was done, chemical addition is not used in present plant operation.

Chemical conditioning of the primary sludge with 2-5% ferric chloride and 10-15% lime on a dry solids basis has resulted in vacuum filter cake solids levels of approximately 20-25%.

By November 1978 most unit processes other than the rapid sand filter were completed, tested, and ready for start-up.

Secondary Treatment System

Since the process schemes of the WRS and activated sludge system are identical, it was possible to operate the treatment facility in an activated sludge mode prior to the addition of activated carbon. With equipment run-in complete, activated sludge operation was begun in mid-November 1978. A major purpose for the activated sludge operation was to begin training the operations staff in treatment system control and ease the later conversion to Wastewater Reclamation. Excess biological solids produced in the secondary system during the activated sludge mode, however, were wasted from the final clarifiers and disposed of with the primary waste sludge.

By mid-December reasonable steady-state operation was obtained. The activated sludge process was operated in a single stage mode at mixed liquor suspended solids concentrations ranging from 2000 to 3000 mg/L and a sludge age (based on aeration solids) of two to three days. The effluent dual media filters were not available for operation during this period as feed and backwash piping remained to be completed.

The performance of the activated sludge system during stable treatment is shown in Table 5. The primary influent BOD_5, COD and suspended solids concentrations of 78 mg/L, 556 mg/L, and 146 mg/L were reduced to approximately 33 mg/L, 237 mg/L, and 40 mg/L in the clarifier effluent; a turbidity of 188 Nephelometric Turbidity Units (NTU) was reduced to 20 NTU. Considerable foaming occured in the aeration basin as expected; at initial start-up color removal exhibited by the activated sludge process was better than that obtained by trickling filter treatment, yet was not satisfactory. Near the later part of this period of operation filamentous bacterial growth was noted in the system which began to affect overall plant operation and performance. At this time the entire system was converted to the WRS.

TABLE 5 ACTIVATED SLUDGE SYSTEM PERFORMANCE

Vernon, Connecticut

Parameter	Raw Influent	Clarifier Effluent
BOD_5, mg/L	78	33
COD, mg/L	556	237
SS, mg/L	146	40
Turbidity, NTU	188	20

*Primary and waste activated sludges were chemically conditioned.

TREATMENT SYSTEM OPERATION AS WRS

Primary Treatment

The preliminary and primary treatment systems have remained in operation to date without chemical addition for pH or suspended solids control.

In March 1979, an accumulation of primary sludge solids occurred due to vacuum filter problems. Due to the inability to vacuum filter the sludge solids and storage of the sludge in the primary clariflocculators, an extremely large volume of septic primary sludge (approximately 1/2 of the primary sludge inventory) overflowed to the secondary system. These sludge solids accumulated in the WRS mixed liquor and were processed along with the excess spent carbon slurry wasted to the Wet Air Regeneration unit. An excess of floatables and scum also reached the secondary system. This condition did not result in a deterioration of effluent quality.

Another problem that resulted in frequent process equipment maintenance is construction debris. This problem persisted throughout the initial year of plant operation. The primary clariflocculators required draw-down and cleaning to remove plastic sheets and pipe wrapping. Similarly, plastics plugged the secondary system scum handling pumps resulting in damage. On numerous occasions, final clarifier draw down and cleaning was necessary to remove wood and other construction debris. During the initial dual media effluent filter testing, construction debris and accumulated crud was washed into the filter beds requiring extensive filter cleaning. In operation of the Wet Air Regeneration unit, frequent plugging of the inlet strainer occurred at times. To minimize this problem, a dual basket strainer was installed to replace the original single basket strainer.

Secondary Treatment

Liquid Treatment

The secondary treatment system was converted from an activated sludge mode to the Wastewater Reclamation system during February 1979, with the addition of a considerable portion of the powdered activated carbon charge to the secondary system. The volatile carbon concentration in the aeration-contact basins was brought up to about one-half of the design concentration. Processing of all excess spent carbon slurry solids in the Wet Air Regeneration unit began at this time. Improved reductions in effluent BOD_5, COD and color levels were obtained in the WRS mode of operation.

The operating conditions during the initial 12 months of WRS operation (March 1, 1979 to March 1, 1980) are presented in Table 6. Several comments are appropriate. The MLSS and volatile carbon concentrations, while adequate to provide a high level of treatment, are lower than the expected design levels. Examination of the WRS performance at a lower volatile carbon level was of interest during the initial treatment plant operation. In addition, lower MLSS levels were considered appropriate during initial operation, anticipating the operator training requirements and construction activities to be completed.

TABLE 6 WASTEWATER RECLAMATION SYSTEM OPERATING DATA

Vernon, Connecticut

Daily Flow, M^3/Day	=	12,730 (3.36 MGD)
Maximum Daily Flow, M^3/Day	=	26,630 (7.03 MGD)
Maximum Sustained Peak Flow, M^3/Day	=	40,900 (10.8 MGD)
Aeration Tank Dissolved Oxygen, Mg/L	=	0.5 - 2.0
MLSS, mg/L	=	11,700
ML Ash, mg/L	=	4,500
Volatile Carbon, mg/L	=	4,300
Biomass, mg/L	=	2,900

The volatile activated carbon concentration maintained in the aeration-contact tanks during this period of operation was approximately 4,300 mg/L. The activated carbon supplied for the initial charge and to replace operating losses was Hydrodarco H. A plot of the monthly average mixed liquor suspended solids concentration is shown in Figure 4.

The suspended ash fraction of the mixed liquor ranges from 30 to 40 percent and results from the carryover of suspended ash from the primary clariflocculators. Control of the MLSS ash fraction is obtained via the regeneration reactor blowdown of inert ash. Reactor blowdown, which occurs during normal steady-state operation of the unit, can be increased or decreased in proportion to the average mixed liquor suspended ash level. The inert ash blown down during regeneration is returned to the grit chamber for disposal with the grit.

The average daily raw wastewater flow rate to the treatment facility during the initial year of operation was 12,730 M^3/day (3.36 MGD) with a peak sustained flow of 40,900 M^3/day (10.80 MGD). The maximum daily raw wastewater flow treated was 26,630 M^3/day (7.03 MGD), approximately a 2:1 maximum day to average day flow ratio.

The average secondary clarifier recycle suspended solids concentration during this period was 31,000 mg/L with an approximate maximum of 60,000 mg/L.

Several important events are noteworthy in the Vernon WRS operation and must be considered when examining the treatment system performance. First, the dual media effluent filter was not operational, except for intermittent periods, until mid-July 1979 due to problems with the motor controls on the filter feed pumps.

The liquid polymer feed system was ineffectual to June 1979 because the polymer piping to the aeration-contact tanks was damaged. Thereafter, carrier/dilution water flow was added to the stock polymer discharge lines to enhance mixing and distribution to the MLSS flow to the secondary clarifiers. The actual liquid cationic polymer addition rates to the WRS range from approximately 0.5 to 1.5 mg/L.

To reinforce piping anchors on the aeration tankage air diffuser piping, each of the four aeration basins was emptied during August and September, 1979. Each repair required about one week to complete.

During November 1979, operation of the Wet Air Regeneration unit was interrupted for nearly a two-week period to complete installation of the spent carbon storage tank and transfer/feed pumps.

A problem throughout this period has been loss of prime of the secondary clarifier recycle pumps and subsequent loss of return sludge capability. Minor modifications were made to allow automatic gas venting from the pump discharge piping in November 1979. Permanent modifications are planned to improve the recycle pump performance and reliability. Until then, higher-than-normal pump rates must be used to overcome loss of prime.

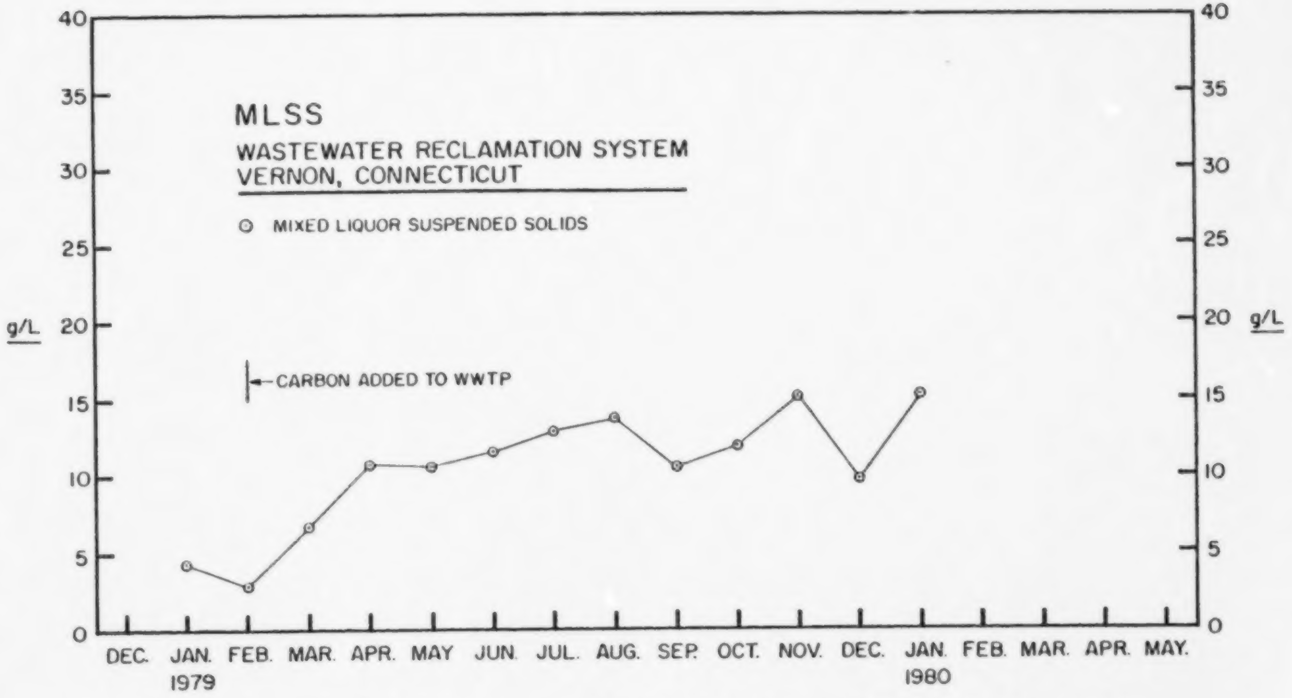


Figure 4. Mixed Liquor Suspended Solids Concentration, WRS; Vernon, CT.

The installation of the excess sludge wasting pumps are not complete, requiring sludge wasting directly from the secondary clarifier recycle. Due to the high wasting rates, large variations in clarifier sludge blanket levels occur. Excessive solids loading rates on the spent carbon thickeners have also occurred.

Solids Processing

The Wet Air Regeneration system has been on-line in support of the secondary wastewater treatment during the entire period of plant operation. The regeneration system operating conditions are presented in Table 7.

TABLE 7 WET AIR REGENERATION SYSTEM OPERATING DATA

Vernon, Connecticut

Feed Solids to Regeneration, g/l	=	83.7
Regeneration Temperature, °C	=	232 ± 5 (450 ± 10°F)
Regeneration Pressure, Kg/cm^2	=	49-53 (700-750 psig)
Flow Rate, L/sec	=	1.5-3.0 (25-50 gpm)
Operating Schedule, hrs/day x days/wk	=	12 x 5

The spent carbon/biomass feed slurry concentration to the regeneration unit averaged approximately 84 g/L and ranged from 60 g/L to slightly greater than 100 g/L suspended solids during this period. This level is somewhat greater than the 60 g/L feed concentration anticipated but allows operation of the regeneration unit at a lower high pressure pump rate than the 3.0 L/sec (50 gpm) nominal design flow rate.

During normal operation of the Wet Air Regeneration unit and during daily start-up of the unit, supplemental fuel addition (steam) is not required; autothermal regeneration is consistently obtained. Due to the heat retention properties of the regeneration unit and the capability of bottling the hot reactor at system pressure, steam addition for start-up is necessary only when the unit has been idle for several days. When operated daily, the WAR unit is simply brought on-line by unbottling the regeneration reactor, adding thickened carbon slurry flow to the system, and adding air. Provided that the initial start is gradual, the regeneration system begins autothermal operation immediately and is fully on-line in approximately one hour.

PERFORMANCE OF WRS

The performance of the pure biological activated sludge system was less than adequate in treating the Vernon combined domestic and industrial wastewater. The inability to treat the highly colored waste is illustrated in Figure 5. With the addition of a small amount of powdered activated carbon to the secondary treatment system, a significant improvement in clarifier effluent quality was obtained.

EPA-287 (Cin.)
(4-70)

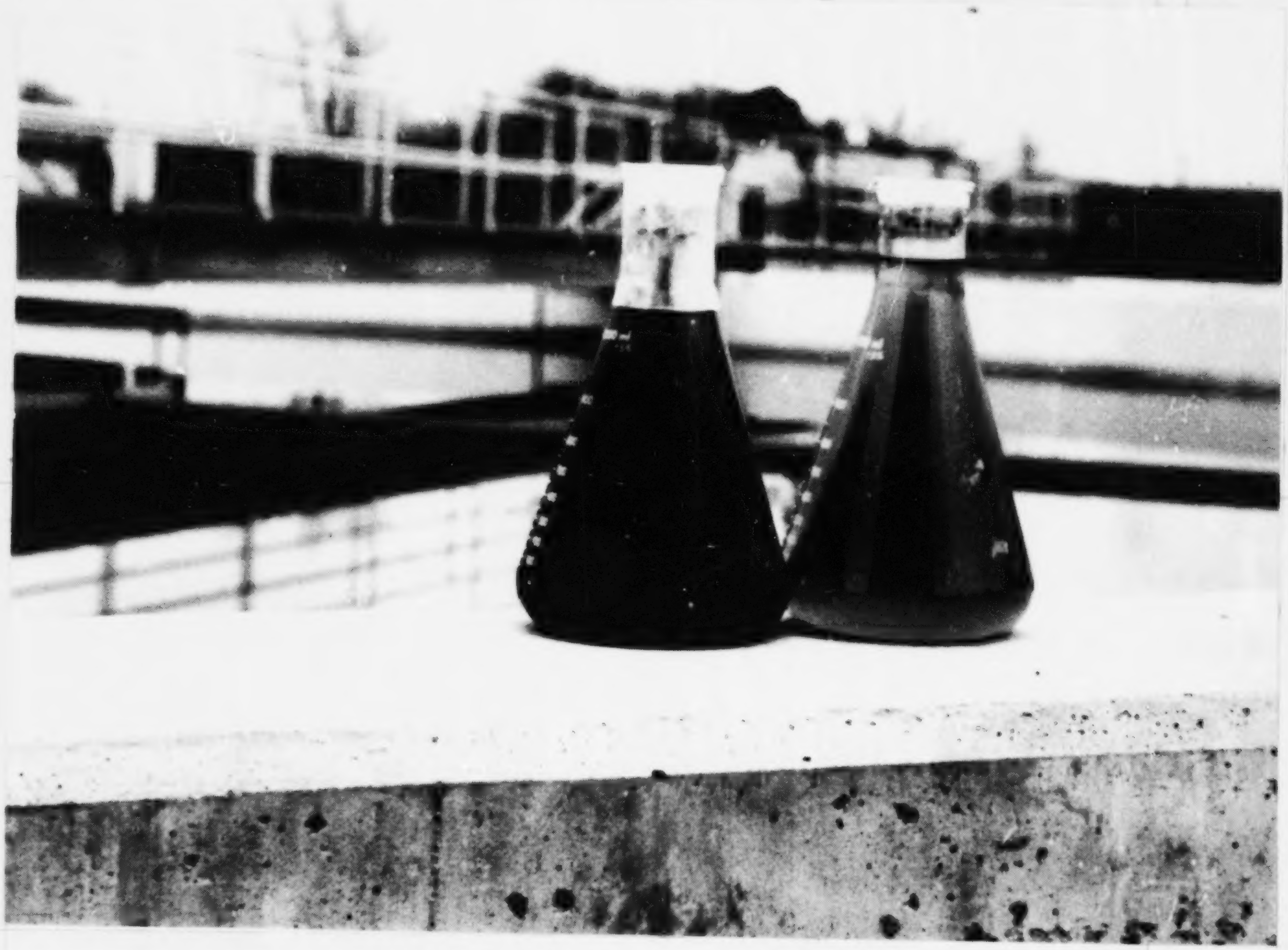


Figure 5. Wastewater Influent and Clarifier Effluent; Activated Sludge Treatment, Vernon, CT

Representative wastewater samples from the present WRS operation are shown in Figure 6, after one year of treatment plant operation. The improvement in color removal is evident. An effluent true color of 20 to 40 APHA is obtained, whereas the raw wastewater color is 150 to 500 APHA and up to 5000 APHA apparent color.

Regeneration of the excess spent carbon slurry from the WRS provided continual reuse of carbon and maintained a high level of waste treatment. Though severe treatment conditions have occurred at times and stressed the WRS operation, performance has been stable. The overall performance results for this twelve-month period, March 1979 to March 1980, are shown in Table 8. All wastewater samples collected are reported in the numerical averages. The average primary influent raw wastewater carbonaceous BOD_5, COD, suspended solids and turbidity concentrations were 200 mg/L, 840 mg/L, 450 mg/L and 148 NTU, respectively. The average effluent carbonaceous BOD_5, COD, suspended solids and turbidity concentrations were 4 mg/L, 73 mg/L, 8 mg/L and 10 NTU, respectively. Prior to mid-July 1979, the effluent results reported are secondary clarifier overflow data. The subsequent performance data is the dual media filter effluent data.

TABLE 8 WASTEWATER RECLAMATION SYSTEM PERFORMANCE

Vernon, Connecticut

Parameter	Raw Influent	Effluent*
BOD_5, mg/L	200	4
COD, mg/L	840	73
SS, mg/L	450	8
Turbidity, NTU	148	10

*Dual media effluent filter placed on-line in mid-July, 1979.

Perhaps a better perspective of the WRS performance is obtained by observing the monthly average BOD_5 data for this period of WRS operation. A monthly average BOD_5 plot is illustrated in Figure 7. The results show that a consistently low effluent BOD_5 has been obtained.

Optimization of Treatment

Since the treatment system at Vernon is still in a semi-start-up mode of operation, optimization of treatment has not been conducted. Upon completion of the plant modifications, this work can be initiated.

Savings in operating costs and optimum performance will be obtained with better manpower utilization and scheduling. Selection of the optimum treatment system operating conditions will also assist. WRS performance at higher aerator mixed liquor carbon concentrations will also be examined.

In summary, the Wastewater Reclamation System at Vernon, Connecticut has performed well to date. Improved performance is expected as optimization of treatment is obtained.

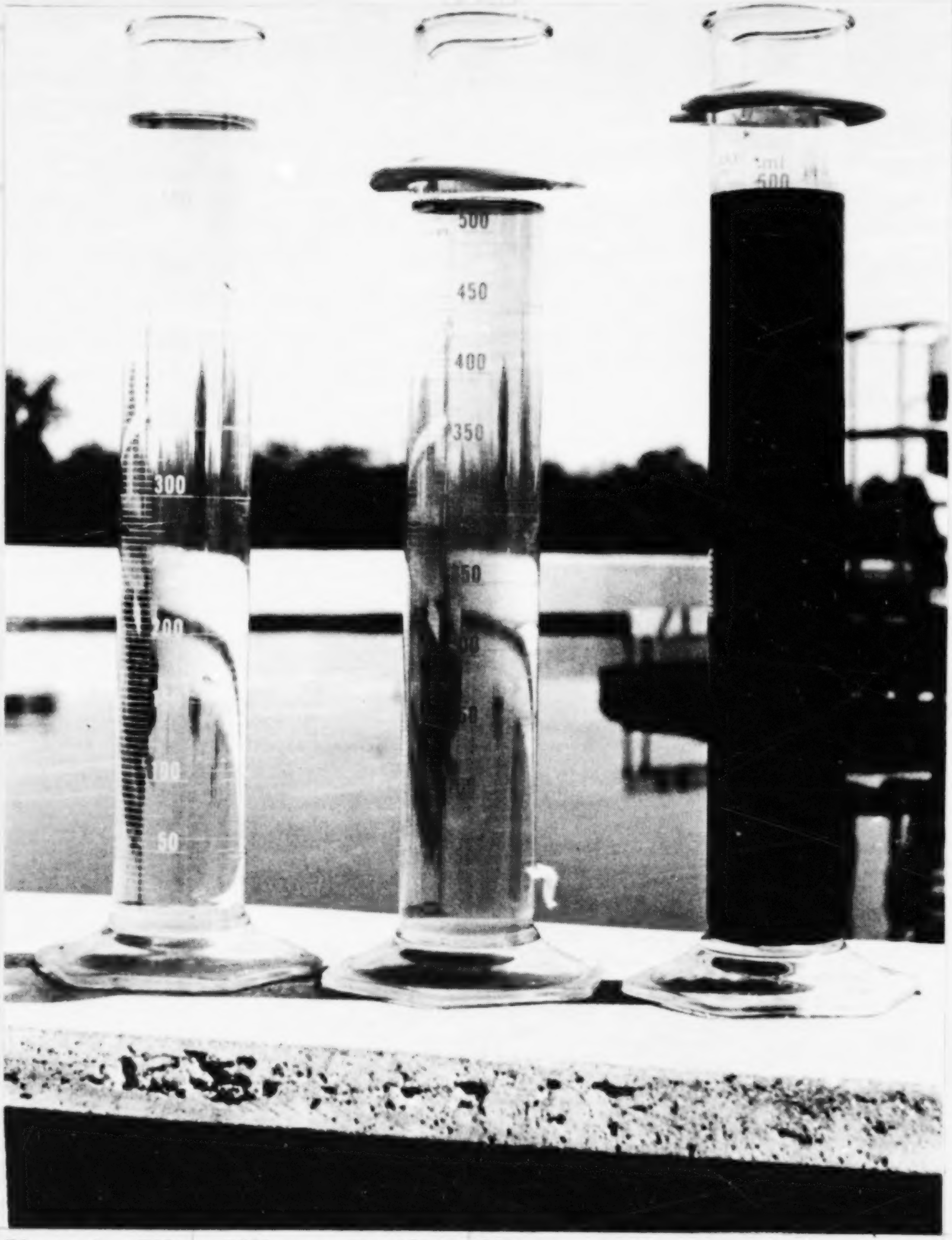

300
200
100
50
500
450
400
350
250
ml
500

Figure 6. Filter Effluent, Clarifier Effluent, and Wastewater Influent; WRS, Vernon, CT.

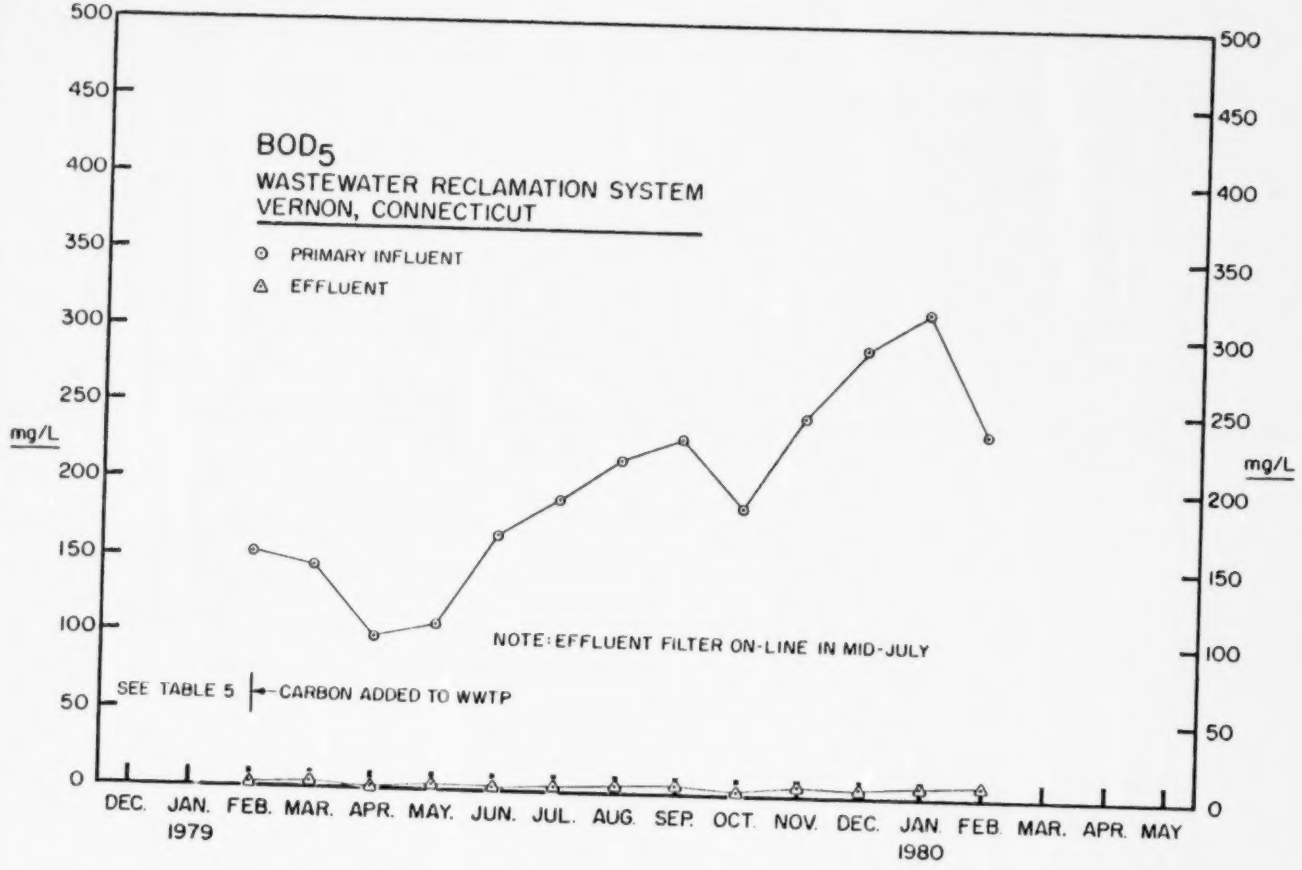


Figure 7. Monthly Average BOD$_5$, WRS; Vernon, CT.

REFERENCES

1. "Standard Methods for the Examination of Water and Wastewater," American Public Health Association, New York, 1975.

2. Barr, J. W., "Biomass and Activated Carbon in Carbon Mixed Liquors; Nitric Acid Digestion Technique," Inter-office correspondence.

REVIEW OF THE USE OF OZONE FOR IMPROVING COMBINED MUNICIPAL/INDUSTRIAL WASTEWATER TREATMENT

R. G. Rice, Ph.D.
Jacobs Engineering Group
1725 K Street, N.W., Suite 608
Washington, D.C. 20006

ABSTRACT

Ozone has been developed for the treatment of sewage since the early 1970's and primarily in the United States. As of today, there are 11 operational sewage treatment plants in the USA using ozonation, another 23 are under construction and another 5 are in design. Most of these plants utilize ozone for disinfection. Full scale plant operational data and data from pilot plant testing upon which full scale plant designs have been developed are discussed. In plants providing tertiary treate[illegible] tewaters, including filtration of secondary effluents, when the wastewater does not contain significant levels of industrial wastes, the average absorbed ozone dosage required to achieve a disinfection level of 200 fecal coliforms/100 mL is 4 to 8 mg/L. However, when significant amounts of industrial wastes are present in the initial sewage, then absorbed ozone dosages can run as high as 10 to 15 mg/L. To attain the more rigid disinfection level of 2.2 total coliforms/100 mL using municipal wastewaters not containing industrial components requires 15 to 20 mg/L absorbed ozone dosage with filtered nitrified secondary effluent and 35 to 40 mg/L of filtered secondary effluent. Other uses of ozone in treating combined municipal/industrial wastewaters include oxidation of organic materials prior to passage through granular activated carbon. This technique appears to provide significant savings in costs associated with operation of granular activated carbon adsorbers.

INTRODUCTION

Since the early 1970's, investigators in the United States have been studying the use of ozonation for disinfecting sewage treatment plant effluents. Many of these studies have been conducted on municipal wastewaters which contain significant amounts of industrial wastes. A few studies have been reported in which ozone has been used for treatment purposes other than disinfection.

Ozone has been used for the disinfection of drinking water supplies in the city of Nice, France, since 1906. Today there are well over 1,000 other drinking water treatment plants throughout the world using ozonation for disinfection and many other purposes (1). Most of these plants are in Europe, as might be expected because it is in Europe that the use of ozone has been pioneered for water treatment. Table 1 lists the primary purposes for which ozone is utilized today in treating drinking water. Most of these uses involve the strong oxidizing ability of ozone.

TABLE 1 APPLICATIONS OF OZONE IN WATER TREATMENT (2)

Bacterial Disinfection
Viral Inactivation
Oxidation of Soluble Iron and/or Manganese
Decomplexing Organically-bound Manganese (oxidation)
Color Removal (oxidation)
Taste Removal (oxidation)
Odor Removal (oxidation)
Algae Removal (oxidation)
Removal of Organics (oxidation) such as pesticides, detergents & phenols
Removal of Cyanides (oxidation)
Suspended Solids Removal (oxidation)
Increase Biodegradability of Dissolved Organics (oxidation) for Biological Removal of Ammonia & Dissolved Organics Upon Passage Through Filtration or GAC Adsorption Media

Europeans do not disinfect sewage, thus use of ozonation techniques for sewage treatment is sparse in Europe as of this time. On the other hand, in the USA, where sewage disinfection is practiced, it was recognized during the late 1960's that chlorination for this purpose was causing sometimes severe environmental insults (3). Consequently, beginning in the late 1960's, a considerable amount of research has been conducted in American sewage treatment plants and institutional laboratories on the use of ozone as an alternative sewage disinfectant to chlorine. This amount of activity has culminated in 11 currently operational sewage treatment plants using ozone, mostly for disinfection. In addition, another 23 American sewage treatment plants are under construction which include ozonation, and at least another 5 plants are being designed with ozonation. Wastewaters entering some of these municipal treatment plants contain significant amounts of industrial wastes which, in turn, can affect the treatment requirements necessary for successful disinfection with ozone. Discussion of this point will be the major theme of this paper.

The use of ozonation for treating industrial wastewater contaminants today in commercial size plants includes such applications as disinfection of waters used for aquacultural purposes, destruction of cyanides in metal finishing effluents, oxidation of organic materials in wastewaters from caprolactam and textiles manufacturing plants, destruction of phenols in and to polish refinery wastewaters, recycle and reuse of spent iron cyanide photographic bleaches and for the recycle of automobile washwaters (14). Many industrial waste components are present in municipal wastewaters and can be treated by means of ozone.

EPA-287 (Cin.)
(4-76)

In Table 2 are listed some of the more significant milestones in ozone technology, as related to water and wastewater treatment, since it was discovered in 1785.

TABLE 2 MILESTONES IN OZONE TECHNOLOGY -- WATER & WASTEWATER TREATMENT

1785	Van Marum noted characteristic odor near electrostatic machine
1801	Cruickshank noted same odor in anode gas during water electrolysis
1840	Schönbein named the substance "OZONE"
1886	de Meritens - first experiments with ozone as a germicide
1893	Oudshoorn, Holland - first drinking water treatment plant to use ozonation
1906	Nice, France - ozone for drinking water disinfection -- ozone has been used continuously
1940	Whiting, Indiana - first USA drinking water plant to use ozone (for taste & odor)
1957	Ozone installed at Boeing Co., Wichita, Kansas, to destroy cyanide in industrial wastewaters
1961	Dusseldorf, Federal Republic of Germany - first use of granular activated carbon following ozonation (drinking water)
1963 (64)	First use of ozone in Swiss (German) swimming pools
1975	Indiantown, Florida - first sewage treatment plant to use ozone (disinfection)
1977	First commercial use of UV/ozone combination to destroy metal cyanide complexes in metal finishing wastewaters

PROPERTIES OF OZONE

Ozone is an unstable gas which boils at minus 112°C (-112°C) at atmospheric pressure and has a characteristic penetrating odor, readily detectable at concentrations as low as 0.01 to 0.05 ppm. By considering the relationships between Henry's Law constants, the solubilities of oxygen (present in air) and ozone in water and the concentrations of ozone and oxygen in air, VENOSA & OPATKEN (4) have shown that the solubility of ozone in water is about 13 times that of oxygen, over the temperature range of 0°C to 30°C.

Additionally, ozone is a powerful oxidant, having an oxidation potential of 2.07 volts in alkaline solution, which is second to that of fluorine. As a result, ozone is capable of oxidizing a great many organic and inorganic species which are found in waters and wastewaters. On the other hand, because ozone is such a powerful oxidant, it is not selective when it functions as an oxidant. This means that when solutions contain easily oxidizable components (BOD, nitrite, free cyanide, bacteria, many constituents which exert a chemical oxygen demand, etc.), all of these materials will be oxidized, assuming that sufficient ozone is provided to the solution to satisfy all immediate oxidant demands.

At the relatively low concentrations of ozone produced by industrial generation equipment (1 to 3% in air; 2 to 6% in oxygen) no explosion hazard exists, but mixtures of ozone concentrated to 15 to 20% or higher in air can be explosive. Currently available ozone generators cannot generate sufficiently high concentrations of ozone in air or in oxygen to be explosive. On the other hand, ozone is a toxic gas, and unnecessary exposures can be detrimental to humans. Care must be taken in designing ozonation systems to utilize proper materials of construction, to guard against leakages of ozone into plant atmospheres and to provide ambient plant air ozone monitoring equipment and safety shut-down features in the event of ozone leakages.

In aqueous solution, ozone is relatively unstable, having a half-life of about 165 minutes in distilled water at ambient temperatures (6). If oxidant demanding materials are present in solution, the half-life of ozone in such solutions will be even shorter. Therefore, ozone applied in small dosages will not provide a long-lasting disinfecting residual in drinking water or in wastewater.

On the other hand, ozone in air (especially under dry conditions) is much more stable than in water. The half-life of ozone in the ambient atmosphere has been determined by the U.S. Environmental Protection Agency to be on the order of 12 hours. In dried air, the stability of ozone is even greater. Thus, ozone can be produced from dry air or oxygen in a water or wastewater treatment plant, then piped considerable distances to the contactors with no fear of losing the product by decomposition back to oxygen.

Before proceeding further, it is important for the newcomer to ozone technology to understand the definitions of some fundamental terms used in discussing the application of ozone so that the data presented in the literature regarding ozonation in aqueous media can be interpreted properly. First of all, the application of the partially soluble ozone to water is effected, in nearly all cases, by passing ozonized air or oxygen through the water in the form of fine bubbles. During the period of time that these ozonized gas bubbles are in contact with the aqueous medium, much of the ozone contained by the gas will be transferred from the gaseous bubble to solution, where the ozone then can react with the soluble or suspended components. However, not all of the ozone applied is transferred from the gas into solution phase. The amount of ozone which does transfer into solution will depend upon the flow rate of ozonized gas through the water, the size of the gas bubbles, concentration of ozone in the gas phase, and the flow rate of water being treated relative to the flow rate of ozonized air or oxygen. Thus it is apparent that some untransferred ozone will be present in the head space of the contactor chamber above the solution.

VENOSA & OPATKEN (4) have developed and STOVER & JARNIS (5) have presented the relationships between applied ozone dosage, absorbed or utilized ozone dosage, and ozone transfer efficiency in the following manners:

The applied ozone dosage (D), in mg of ozone per L of liquid, is determined by the equation:

$$D = Y_1(Q_G/Q_L)$$

where: Y_1 = mg of ozone/L of carrier gas

Q_G = flow rate of carrier gas, L/min

Q_L = liquid flow rate, L/min

The ozone transfer efficiency, %TE, is defined by the equation:

$$\%TE = [Y_1 - Y_2]/[Y_1] \times 100\%$$

where: Y_2 = mg ozone/L in gas phase leaving the ozone contactor

The absorbed ozone dosage, A, in mg of ozone absorbed/L of liquid, is defined by the equation:

$$A = D \times \%TE$$

Substituting for D and %TE and simplifying gives:

$$A = Y_1(Q_G/Q_L)[Y_1 - Y_2]/[Y_1], \text{ and}$$

$$A = (Q_G/Q_L)(Y_1 - Y_2)$$

Therefore, as pointed out by STOVER & JARNIS (5), those principal factors which affect the performance of ozone in disinfecting municipal (or combined municipal/industrial) wastewaters (water quality, % ozone transfer efficiency and absorbed ozone dosage) become key issues in evaluating the feasibility and economics of designing such systems and should be established for each specific ozone application, rather than relying upon generalities in the published literature.

Unfortunately, much of the early literature regarding the application of ozone to disinfection of municipal wastewaters as well as to the treatment of industrial and combined municipal/industrial wastewaters refers only to the applied ozone dosages, without specifying flow rates of gas and liquid (Q_G/Q_L) or the amount of ozone remaining in contactor off-gases (Y_2). In the balance of this presentation we shall discuss only those projects in which all of the above parameters were reported.

HISTORY OF OZONE IN MUNICIPAL WASTEWATER TREATMENT

It was recognized in the late 1960's that the use of chlorination for disinfecting sewage treatment plant effluents was producing toxic effects on aquatic life in receiving bodies of water (3). As a result, demonstrations of the use of ozonation were conducted, some of these sponsored by the U.S. Environmental Protection Agency.

Wynn et al. (6) conducted an extensive pilot plant study of ozonation for tertiary treatment of several different types of secondary effluents at the Washington, D.C. Blue Plains treatment plant. NEBEL et al,

(7) conducted an extensive pilot plant study at Louisville, Kentucky on an oxygen-activated sludge effluent. ROSEN et al. (8) described pilot plant programs conducted at Fairfax, Virginia; Dallas, Texas; St. Paul, Minnesota and Hendersonville, Tennessee. Many other pilot plant studies have been conducted and most of these have been reported in the proceedings of meetings of the International Ozone Association held since 1973 (9-12). Results of some of these studies, particularly those involving combined municipal/industrial wastewaters, will be discussed later in this presentation.

In November, 1975, the 0.5 mgd sewage treatment plant at Indiantown, Florida, began disinfecting its effluent with ozone. This was the first full scale application for ozone in sewage treatment. The Indiantown plant has been operating satisfactorily ever since. Ozone dosages of 7.5 mg/L attain a fecal coliform level of less than 70/100 mL (13) in wastewaters which do not contain industrial contributions.

As of March 1980, there are 11 U.S. sewage treatment plants operating on full-scale with ozonation -- these plants are listed in Table 3. At the same time, an additional 23 U.S. are under construction incorporating ozone-- these are listed in Table 4. Finally, Table 5 lists 5 additional plants which are being designed and in which ozone has been incorporated into the treatment process. As details of successful and cost-effective operation of these plants become available to the engineering community, even more extensive use of ozone in sewage treatment can be anticipated in the future.

MUNICIPAL WASTEWATER TREATMENT WITH OZONE

Table 6 lists pertinent data concerning some of the full scale municipal wastewater treatment plants using ozone for disinfection and which do not contain significant amounts of industrial wastes in their influent waters. In this table we are concerned with the use of ozone for disinfection, the type of wastewater treatment before ozonation, the amount of industrial waste contained in the influent to the sewage treatment plant (none), and the absorbed dosage of ozone required to attain the desired level of disinfection.

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

TABLE 3 OPERATIONAL USA SEWAGE TREATMENT PLANTS USING OZONE (MARCH, 1980)

Location	System Type	Start-Up Date	Average Flow, MGD
Indiantown, FL	Air/O_3	1975	0.5
Woodlands, TX	Air/O_3	1976	1.5
Upper Thompson Sanitation District, CO	Air/O_3	1977	1.5
Chino Basin, CA*	Air/O_3	1978	5.0
Palo Alto, CA**	Air/O_3	1978	4.0
Harriman, NY	Air/O_3	1978	---
Collegeville, MN	Air/O_3	1978	0.22
Mahoning County, Oh***	O_2/O_3	1978	4.0
Hunter Highlands, NY	Air/$_3$	1978	< 1
Cotter Gasville, AR	Air/O_3	1978	1
Springfield, MO***	O_2/O_3	1978	35

All plants except Chino Basin and Palo Alto use ozone for disinfection.
* Chino Basin uses ozone to remove suspended solids.
** Palo Alto uses ozone prior to GAC adsorption and filtration.
*** Plants using oxygen-activated sludge process.

It will be apparent from the data of Table 6 that the absorbed ozone dosages required to attain the disinfection level of 200 fecal coliforms/100 mL are in the range of 4 to 8 mg/L. The Hunter Highlands, New York plant is attaining a disinfection level of zero fecal coliforms/100 mL, but utilizes a very clean, tertiary treated effluent.

On the other hand, it is equally important to observe that at all of the operating plants rather extensive tertiary and/or advanced wastewater treatment is practiced before ozonation. This results in rather clean effluents, which should contain much lower levels of suspended solids (10 mg/L or less) than would effluents processed by activated sludge or oxygen activated sludge alone (about 30 mg/L). Such high quality effluents may be the reason that ozone dosages required to attain 200 fecal coliforms/100 mL disinfection levels are relatively low (4 to 8 mg/L). For example, it has been shown by SPROUL *et al.* (18) that encasement or adsorption of enteric bacteria and viruses in fecal material and HEp-2 cells protects these microorganisms from concentrations of ozone that would normally destroy or inactivate them in the unadsorbed, free state. Thus a basic principle in consideration of ozone for wastewater disinfection would appear to be the provision of an effluent containing the lowest suspended solids concentration as practicable or cost-effective under the local circumstances.

BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
BEGIN LAST LINE OF TEXT
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

TABLE 4. USA SEWAGE TREATMENT PLANTS USING OZONE--UNDER CONSTRUCTION, MARCH, 1980

Location	Feed Gas	Estimated Start-up	Average Flow, MGD
Oak Ridge, NY	Air	1980	0.12
Norton AFB, CA	Air	1980	0.25
Carmel, NY	Air	1980	1.
Potomac Heights, MD	Air	1980	0.2
Murphreesboro, TN*	Oxygen	1980	8
Casper, WY	Air	1980	<1
Pensacola, FL*	Oxygen	1980	20
Hercules, CA	Air	1980	0.4
Marion, NY	Air	1980	<1
Brookings, SD	Air	1980	6
Concord, NC*	Oxygen	1980	25
Delaware County, OH	Air	1980	1.5
Frankfort, KY	Air	1980	7
Granby, CO	Air	1980	<1
Yaphank, NY	Air	1980	0.12
Hagerstown, MD*	Oxygen	1981	8
Holland, MI*	Oxygen	1981	5
Ocean City, MD*	Oxygen	1981	12
Olympia, WA*	Oxygen	1981	14 (35 peak)
Rocky Mount, NC*	Oxygen	1981	14
Madisonville, KY*	Oxygen	1980	5
Indianapolis, IN (Richmond)	Oxygen	1981	125
Indianapolis, IN (Belmont)	Oxygen	1981	125

All plants will use ozone for disinfection.
* Plants using oxygen-activated sludge process.

TABLE 5. USA SEWAGE TREATMENT PLANTS USING OZONE - IN DESIGN, (MARCH, 1980)

Location	Feed Gas	Estimated Bid Date	Average Flow, MGD
Cleveland, OH (Westerly)**	Oxygen	1980	50
Tacoma, WA*	Oxygen	1981	60
Vale, CO	Air	1980	8
Henrico County, VA*	Oxygen	1981	
Lynn, MA*	Oxygen	1981	25

*Plants using oxygen-activated sludge process.
** A physical/chemical process with ozonation followed by GAC adsorption (ozone-enhanced BAC).

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
EPA-287 (Cin.) (4-76)

On the other hand, BHARGAVA (20), in discussing the evaluation of ozonation for the new Murphreesboro, TN plant, concluded that if only 25% more ozone is required to disinfect the oxygen activated sludge treated plant effluent without filtration, then filtration before ozonation would not be cost-effective. The Murphreesboro plant is scheduled to start operating shortly, and operating data to confirm this point should be available later in the year.

All of the remaining plants listed in Table 6 and scheduled to begin operating in 1980, initially will apply 4 to 10 mg/L of absorbed ozone dosages to attain disinfection levels of 200 fecal coliforms/100 mL. It is interesting that the plants at Frankfort, KY (30) and Delaware County, OH (19) appear to have specified ozone dosages without conducting pilot plant testing at either site. Both influent wastewaters contain very little, if any, industrial contaminants, so that the primary concern in being able to attain satisfactory disinfection with ozonation would appear to be with the suspended solids content of the treated wastewaters. Performance data for these two plants are anxiously awaited to confirm or deny the dosages of ozone which actually will be required. Delaware County, OH has installed 10 mg/L ozone dosage capability, but may be able to attain their disinfection objective with considerably less.

In Table 7 are listed four oxygen activated sludge municipal wastewater treatment plants which are (Springfield, MO) or will be (Olympia, WA and the two Indianapolis, IN plants) using ozone for disinfection and whose influent wastewaters also contain significant industrial waste loadings. At Indianapolis some 40% of the flow and 70% of the strength are comprised of light industrial wastes (pharmaceutical, food and starch manufacturing, bottle manufacturing)(21).

TABLE 6. OZONE DISINFECTION OF MUNICIPAL WASTEWATERS AT OPERATING PLANTS OR PLANTS UNDER CONSTRUCTION

Location	industrial components	treatment before ozonation	avg. flow rate, mgd	av. absorbed ozone, mg/L	plant startup date	Remarks
Indiantown, FL	none	Imhof tank, trickling filter, coagulation (polyelectrolyte, laminar filtration.	0.5	7.5	1975	attains 70 fecal coliforms/100 mL (13).
Woodlands, TX	none	biological, lime, coagulation, CO_2.	1.5	8	1976	obtains 200 fecal coliforms/100 mL.
Upper Thompson Sanitation District, CO	none	Act. sludge, nitrification, trimedia filtration.	1.5	6	1977 (15)	obtains 200 fecal coliforms/100 mL. Ozone transfer effic. 50-60%.
Mahoning County, OH	none	2-step oxygen acivated sludge w/ lime in 2nd step, clarif., floccn., recarbn., dual media filtrn.	4	6	1978	obtains 200 fecal coliforms/100 mL (16).
Hunter Highlands, NY	none	extnd. aeration, Neptune microfloc filtration	80,000 gpd	1	1978	attains zero fecal coliforms/100 mL
Oak Ridge, NY	none	screen, RBC, Neptune microfloc filtration	0.12	30-40	1980	designed to obtain zero fecal coliforms/100 mL
Murphreesboro, TN	small; enters in slugs	oxygen act. sl. w/ 2-stage nitrif. + filtration	8	6	4/1980	to obtain 200 fecal coliforms/100 mL. No pilot studies done.

TABLE 6. (Continued)

Location	industrial components	treatment before ozonation	avg. flow rate, mgd	av. absorbed ozone, mg/L	plant startup date	Remarks
Pensacola, FL	none	oxygen act. sl. ; filtration	20	5	5/1980	to attain 200 fecal coliforms/100 mL.
Frankfort, KY	v. little	extended aeration oxidation ditch ; no filtration	7	4 (30)	4/1980	to attain 200 fecal coliforms/100 mL. No pilot testing conducted.
Delaware County, OH	none	act. sludge	1.5	10 (max)	1980	to attain 200 fecal coliforms/100 mL. No pilot testing done.
Brookings, SD	none	act. sludge	6	7	late 1980	to attain 200 fecal coliforms/100 mL
Granby, CO	none	?	<1	6-8	1980	to attain 200 fecal coliforms/100 mL
Madisonville, KY	?	oxygen act. sl.	5	6.5	4/1980	to attain 200 fecal coliforms/100 mL

TABLE 7. OZONE DISINFECTION OF MUNICIPAL WASTEWATERS CONTAINING INDUSTRIAL COMPONENTS

Location	industrial components	treatment before ozonation	avg. flow rate, mgd	av. absorbed ozone, mg/L	plant startup date	Remarks
Springfield, OH	food processing, light indl. (milk, pharmaceut.	primary settlg., oxygen act. sl., air nitrif. act. sl., tri-media filtrn.	35	10	1978	attains 200 fecal coliforms/100 mL w/3% O_3 in oxygen.
Olympia, WA	60% brewing	oxygen act. sl. without filtrn.	14 (35 pk)	10*	1981	to attain 200 fecal coliforms/100 mL.
Indianapolis, IN	pharmaceut., food procsg., starch mfg., bottle mfg.	trickling filt., oxygen act. sl., nitrification, filtration.	2 plants, 125 mgd ea.	5	1981	to attain 200 fecal coliforms/100 mL.

* Dosage of 10 mg/L specified without pilot plant studies.

The Springfield plant wastewater receives nitrification and tri-media filtration after oxygen activated sludge, and still requires an absorbed ozone dosage of 10 mg/L to attain the disinfection target of 200 fecal coliforms/100 mL. Without filtration, some 2 to 3 times this dosage would have been required (22). On the other hand, the two Indianapolis plant wastewaters will receive nitrification and filtration after oxygen activated sludge, but these plants are designed to receive only 5 mg/L of absorbed ozone dosages. These dosage levels have been confirmed during two different pilot plant studies (23).

At the Olympia, WA plant, about 60% of the sewage to be treated comes from the local brewing company. These wastes are high in readily degradable BOD_5, which are expected to be treated to acceptable levels by the oxygen activated sludge process. Rather high levels of ozone (10 mg/L absorbed dosage) have been designed into the plant to attain disinfection. On the other hand, no pilot plant testing has been reported on this wastewater (24). It remains to be seen whether disinfection of this wastewater can be attained with less than 10 mg/L ozone dosage, without the need for filtration before ozonation.

PILOT PLANT OZONATION STUDIES ON COMBINED MUNICIPAL/INDUSTRIAL WASTEWATERS

LOUISVILLE, KENTUCKY (7)

Sewage influent to the Fort Southworth plant contains 60% industrial waste loading, which includes dyestuffs and highly variable COD levels. The pilot plant study involved passing the available primary treated effluent through an oxygen activated sludge pilot plant unit. An applied ozone dosage of 15 mg/L (non-filtered effluent) was required to attain a 200 fecal coliform/100 mL disinfection level.

The 15 mg/L of absorbed ozone dosage provided the additional performances listed in Table 8, including nearly 100% inactivation of viruses, 99+ removal of total coliform, fecal coliform and fecal streptococci bacteria and 70% and 29% reduction in turbidity and COD levels, respectively. In addition, the ozonized effluent produced no noticeable harmful effects on native fish populations, whereas non-ozonated secondary effluent was toxic in a test study.

DALTON, GEORGIA (25)

More than 200 carpet-producing and related firms provide 90% of the wastewater loading to the Dalton, GA treatment plant, which provides primary then secondary treatment. The effluent from this plant, however, contains high color and COD levels (an average of 275 APHA units and 150 mg/L of COD, respectively). A pilot plant study was conducted to determine the efficacy of treating this unfiltered effluent with ozone to lower the color from the average 275 to 30 APHA units. Such treatment was found to require absorbed ozone dosages of 45 mg/L. Equivalent color removal also could be obtained by means of granular activated carbon adsorption, requiring 780 mg/L dosages of GAC.

TABLE 8. OZONATION TEST RESULTS--LOUISVILLE, KY (32; 7)

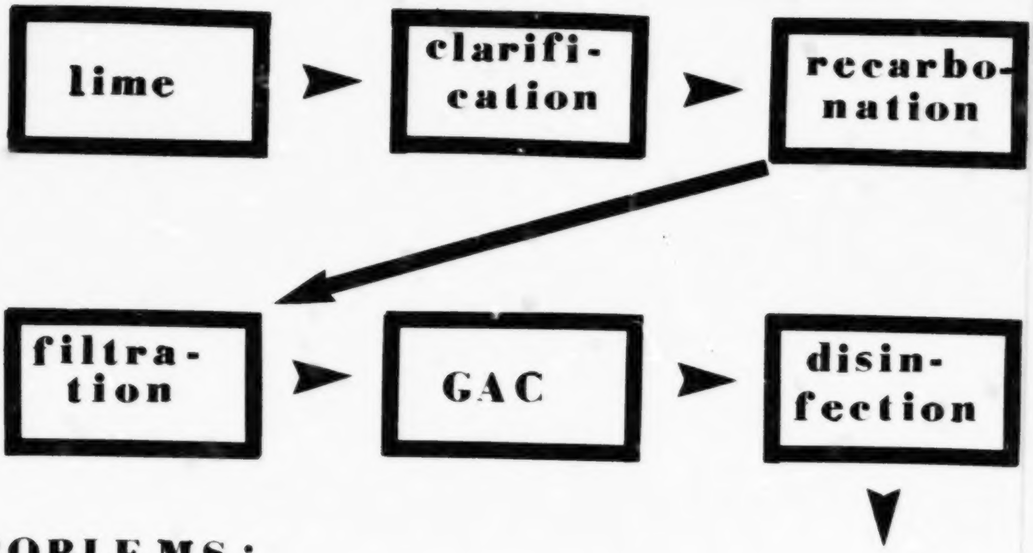
Average absorbed ozone dosage	:	15 mg/L
Effluent type	:	Oxygen activated sludge
Effluent analyses		
total coliforms	:	500/100 mL
fecal coliforms	:	103/100 mL
fecal streptococci	:	9/100 mL
viral inactivation	:	nearly 100% after 5 minutes ozone contact time & residual of 0.05 mg/L
average turbidity removal	:	70%
average COD removal	:	29%
average color removal	:	79%
average BOD removal	:	15%
average TOC removal	:	15% to 20%

Table 9 shows the results obtained by application of 45 mg/L of ozone to this combined municipal/industrial wastewater. Not only was the color objective attained, but also significant reduction in levels of COD (40%), suspended solids (85%), biphenyl content (51%), anionic detergent content (92%), fecal coliforms (100%) and total coliforms (99.99%). In addition, inorganic carbon levels increased 67% (showing that considerable organic carbon was converted into CO_2) and dissolved oxygen increased from 2 to 8.5 mg/L.

WYOMING, MICHIGAN (26)

Wastewater influent to this plant contains 35% to 45% light industrial wastes from metal plating, dairy products and other commercial establishments. Significant quantities of phenolic compounds also are present in the wastewater (31). A pilot plant study was performed to compare the disinfecting performance of ozone, chlorine (with and without dechlorination) and bromine chloride, then to determine the toxicity of the disinfected effluents to aquatic life (26).

Absorbed ozone dosages averaging 7.4 mg/L gave fecal coliform levels averaging 68/100 mL from a filtered trickling filter effluent during most of the study. True color was lowered upon ozonation from 86 to 36 Pt-Co units, but COD was unaffected. The ozonized effluents did not show detrimental effects upon survival of fathead minnows. Acute toxicity tests conducted on fathead minnows showed less mortality with ozonized effluents than with effluents treated with the other disinfectants, but only the ozonized effluent was filtered before disinfection. It was also observed that ozone dosage levels required to attain disinfection were more dependent upon the effluent quality than were the other disinfectants.



lime

clarification

recarbonation

filtration

GAC

disinfection

PROBLEMS:

- regenerate GAC every 30-40 days
- sulfidic odors
- erratic TOC values
- erratic disinfectant demands

Figure 1. Westerly plant, Cleveland, Ohio—original design.

EPA-287 (Cin.)
(4-76)

TABLE 9. TREATMENT OF DALTON, GA UNFILTERED EFFLUENT WITH 45 MG/L OZONE

Parameter	Initial	Final	% Change
Color	275 APHA	30 APHA	- 89%
COD	156 mg/L	94 mg/L	- 40%
BOD	21 mg/L	21 mg/L	0%
DO	2 mg/L	8.5 mg/L	+ 325%
Organic Carbon	53 mg/L	54 mg/L	+ 2%
Inorganic Carbon	3 mg/L	5 mg/L	+ 67%
Suspended Solids	20 mg/L	3 mg/L	- 85%
Biphenyl	1.85 mg/L	0.90 mg/L	- 51%
Anionic Detergents	0.6 mg/L	0.05 mg/L	- 92%
Fecal Coliforms	8,000/100 mL	0/100 mL	-100%
Total Coliforms	850,000/100 mL	2,500/100 mL	- 99.99%
pH	6.8	7.1	+ 4%

CLEVELAND, OHIO (WESTERLY PLANT)

At Cleveland's 50 mgd Westerly plant, influent wastewaters contain about 45% of wastes from chemical plants, a steel mill, slaughterhouses and paint companies. The Westerly sewage currently is treated by a physical-chemical process which includes granular activated carbon adsorption as a late step for removal of dissolved organics prior to disinfection. The flow scheme for this treatment plant, as originally placed in operation, is given in Figure 1. Data reported were determined on a 30 gpm pilot plant unit which was operated 24 hours/day, 7 days/week (33). Originally, ozone was studied for providing disinfection to the GAC column effluent.

During early stages of operation of this pilot plant, however, it became apparent that the effluent characteristics varied greatly from day to day. High iron levels in the wastewater influent required high lime dosages. In addition, incoming levels of phosphorus approached the detection level, negating the effects of pH control for phosphorus removal. In turn, these variations caused decreases in capture of suspended materials in the clarifier (up to 38% increases in clarifier effluent during periods of high iron conditions). Also, the quality of the sludge changed considerably in terms of volatile matter contained, and a significant amount of iron was resolubilized during recarbonation.

Additionally, GAC adsorption failed to consistently produce an effluent which met the treatment objectives for BOD and COD, even at low cumulative loadings. Sulfidic odors developed in the GAC adsorber, caused by anaerobic microorganisms which evolved in the low dissolved oxygen environment, and the ozone demand of the GAC effluents to attain the disinfection level of 200 fecal coliforms/100 mL varied widely. Resolubilized iron was reduced and adsorbed on the GAC, and interfered with restoration of adsorption capacity of the GAC upon thermal regeneration. A noticeable reduction in both soluble iron and soluble COD took place during ozonation 90% of the time, but the total TOC remained unchanged, indicating that the organic materials present were being changed chemically, rather than being oxidized to CO_2 and water.

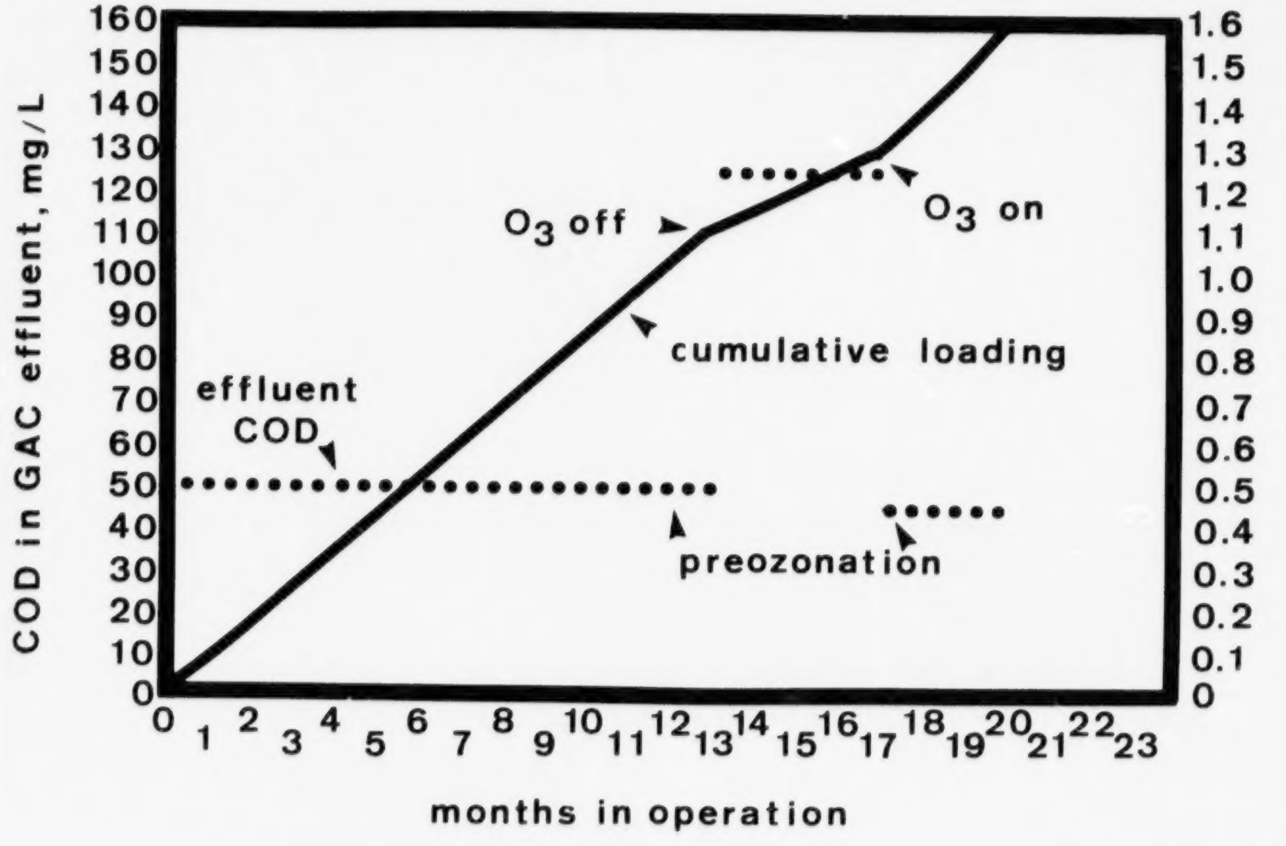


Figure 2. Performance of GAC pilot plant unit with and without preozonation - Cleveland.

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
DROPPED HEAD BEGIN SECTIONS HERE
CENTER OF PAGE
TOP OF IMAGE AREA
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE R
EPA-287 (Cin.)
(4-76)

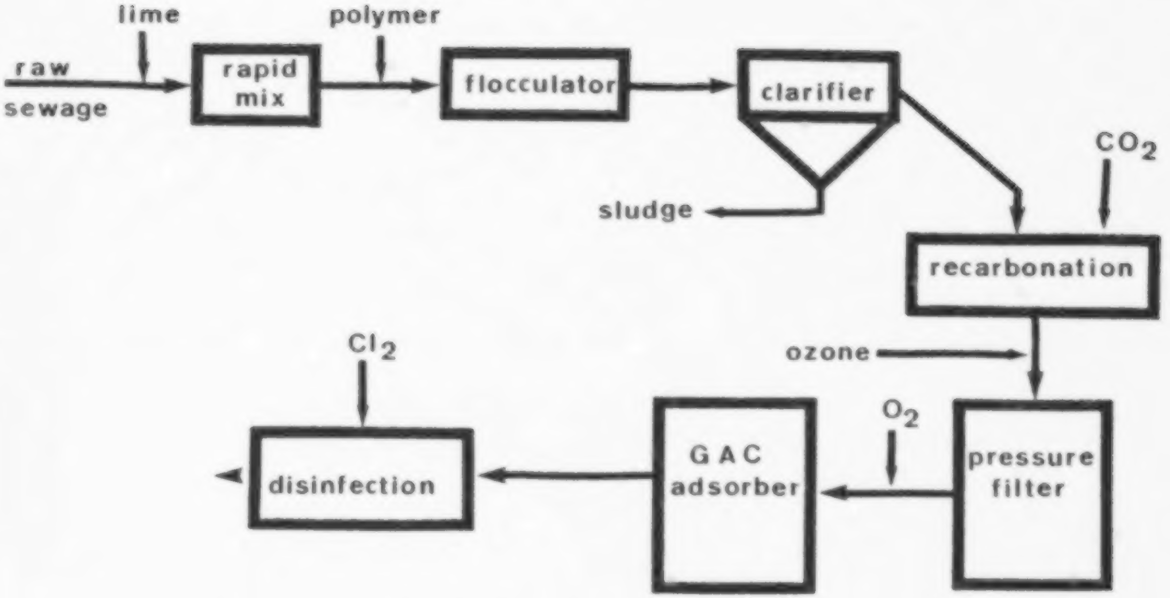

lime
polymer
raw sewage
rapid mix
flocculator
clarifier
sludge
CO_2
recarbonation
ozone
O_2
pressure filter
GAC adsorber
Cl_2
disinfection

Figure 3. Modified treatment process at Cleveland, Westerly plant.

In attempts to correct these problems, ozonation was moved from after GAC adsorption to after recarbonation, but before the pressure filtration step. This immediately elevated the dissolved oxygen levels in the ozonized, recarbonated wastewater. As a result, biological growths became aerobic and the sulfidic odors disappeared from the GAC column. Performance of the GAC column became quite consistent and disinfectant demands became constant. Details of the changes made to the Westerly pilot plant process and their effects have been published by GUIRGUIS et al. (27).

Based upon these successful pilot plant results, ozonation has been designed into the full scale Westerly treatment plant as a chemical oxidant (not for disinfection) before the GAC adsorption step at applied dosages of about 8 mg/L step for several reasons. First, the presence of dissolved oxygen in the GAC influent will prevent anaerobic biological growths in the GAC columns, and therefore prevent the generation of hydrogen sulfide in the system. Second, the higher molecular weight polymers which are not readily adsorbed by the GAC are cracked into lower molecular weight fragments which are better adsorbed. Thirdly, a major proportion of the biorefractory organic materials is partially oxidized upon ozonation, producing organic materials which are more easily biodegraded. These partially oxidized organics are biodegraded in the GAC adsorption columns. Finally, soluble iron will be oxidized to the ferric state, in which it will hydrolyze and be filtered out of the system before coming into contact with the GAC adsorber, prolonging the life of the GAC.

The biologically enhanced granular activated carbon medium has been found to have a prolonged useful life before thermal reactivation is required. In pilot plant studies, GUIRGUIS, et al. (27) showed that the GAC column without a preceding ozonation step was unable to remove BOD sufficiently to meet the EPA discharge standards nor to remove COD to consistent levels. In addition, the GAC had to be thermally reactivated every 30 days. By contrast, when sand filtration then GAC adsorption followed an ozonation step (5 to 6 mg/l), not only did the column effluent meet the BOD discharge limitation, but the COD content became constant and the GAC was used for 21 months without having to be reactivated. When ozonation was discontinued, immediate breakthrough of organics (COD) was observed; however when ozonation was restarted, the GAC column performance quickly returned to its steady state condition of meeting the required discharge standards. This behavior is shown in Figure 2 (28).

Based on these results, Cleveland is designing 6,700 lbs/day of ozone generation capacity (from oxygen) into the Westerly plant prior to GAC adsorption. Chlorine disinfection still is practiced after GAC adsorption, because it is cost-effective over the 10 mg/L of ozone which would be required (28). The process to be installed is shown schematically in Figure 3.

The Palo Alto, California wastewater treatment plant has incorporated ozonation prior to GAC adsorption (29), which has been operating since 1978, whereas the ozone/GAC process will not be operating in the full-scale Westerly plant until 1981. Data on the performance of the system as well as cost savings in GAC reactivation from both of these sewage treatment plants are anxiously awaited.

MARLBOROUGH, MASSACHUSETTS (5)

Although the sewage treated with ozone at this location is primarily municipal, there are several aspects of this plant which are of significance to this discussion. At Marlborough, a pilot plant study has been conducted to evaluate ozone as a wastewater disinfectant to attain the very stringent 2.2 total coliforms/100 mL disinfection standard, currently required by the California State Department of Health for non-restricted recreational uses of wastewater.

Secondary effluent and nitrified secondary effluent were treated with ozone with and without prior dual media filtration. Absorbed ozone doses of between 2 and 35 mg/L were applied to these effluents at contactor hydraulic reaction times of 1 to 10 minutes, yielding total effluent residual oxidant concentrations of 0.4 to 8.0 mg/L. Absorbed ozone doses necessary to achieve less than 2.2 total coliforms/100 mL and 70 total coliforms/100 mL are given in Table 10. Filtered nitrified effluent required absorbed ozone dosages of 15-20 and 5-10 mg/L to attain less than 2.2 and 70 total coliforms/100 mL, respectively; filtered secondary effluent required 35-40 and 15-20 mg/L of ozone to attain less than 2.2 and 70 total coliforms/mL, respectively. Fecal coliforms were never detected in the ozonated effluents which contained less than 2.2 total coliforms/100 mL.

TABLE 10. ABSORBED OZONE DOSAGES REQUIRED FOR DISINFECTION AT MARLBOROUGH, MA

Effluent	Absorbed Ozone Dose, mg/L
to attain less than 2.2 total coliforms/100 mL	
Filtered Nitrified	15 to 20
Filtered Secondary	35 to 40
to attain 70 total coliforms/100 mL	
Filtered Nitrified	5 to 10
Filtered Secondary	15 to 20

COSTS OF OZONE TREATMENT

Costs should be determined on a site-specific basis and compared with the costs of alternative treatment processes considered for attaining the specific treatment objective(s). It should also be borne in mind that chemicals added for one purpose, say disinfection, can result in other benefits or detriments. For example, the use of chlorine for wastewater disinfection now is known to produce chlorinated by-products and/or residual chlorine levels which must be removed in some regions by a dechlorination step, which will add to the treatment costs. On the other hand, ozonation for wastewater disinfection has been shown to lower color levels, COD, suspended solids, inactive viruses and increase the level of dissolved oxygen. However, if the wastewater must be filtered before ozonation, these costs also must be considered as a consequence of selecting ozone as the treatment process.

In most cost comparisons which have been made to date, ozonation is reported to be about as costly as chlorination/dechlorination, when the wastewater requires 4 to 8 mg/L to attain the required level of disinfection.

In more specific terms, however, recent studies of VENOSA & OPATKEN(4), and performance data from some of the operating wastewater and drinking water treatment plants currently using ozone provide the most meaningful data to the design engineer.

Based on pilot plant studies at EPA's Municipal Environmental Research Laboratory in Cincinnati it has been shown (4) that the major cost (36%) of ozone disinfection of wastewater is amortization of fixed capital investment. The power cost to generate ozone comprised 17% of the total cost, assuming 3¢/kWh for the cost of electricity in 1979. Operating labor (0.5 man-year) comprised another 16% of the total. Assuming an absorbed ozone dosage of 5 mg/L and 85% ozone transfer efficiency, VENOSA & OPATKEN (4) calculated that the total cost of ozone disinfection at a 1.3 mgd treatment plant amounts to 11¢/1,000 gallons. Scaling up to a 10 mgd plant would lower amortization costs 40% and operating labor costs by 80%; thus the total cost of ozone disinfection would drop to 4.3¢/1,000 gallons at this level of use.

During the early phases of operation of the Upper Thompson Sanitation District's 1.5 mgd wastewater treatment plant (during which time the plant operated at an average rate of 0.7 mgd), treatment costs for ozonation were approximately 10¢/1,000 gallons (34). However, in a later report, RAKNESS & HEGG (15) showed that even though the transfer efficiency of the ozone contactors at this plant are only 50% to 60%, ozonation costs to attain less than 200 fecal coliforms/100 mL are about 7.5¢/1,000 gallons. If the ozone transfer efficiency could be increased to 90%, then ozonation costs at the Upper Thompson Sanitation District could approach 5 to 6¢/1,000 gallons.

Using cost data developed by EPA (4), overall costs per mg/L of absorbed ozone dose equate to 2.2¢ at a 1.3 mgd plant and 0.86¢ at a 10 mgd plant (assumptions: 85% ozone transfer efficiency and 3¢/kWh electricity cost). Operating data at the 1.5 mgd Upper Thompson Sanitation District show costs on the same basis to be 1.5¢, with an ozone transfer efficiency of only 50% to 60%. This figure would approach 1.0¢ at 90% to 95% ozone transfer efficiency.

In early 1979, the new 18 mgd Monroe, Michigan drinking water treatment plant started operating using ozone for taste and odor control (35). During the first 6 months of operation, an average of 1.63 mg/L of absorbed ozone dosage was used and the average ozone transfer efficiency was 96%. The costs for treating Monroe's drinking water with ozone were reported (35) to be 0.636¢/1,000 gallons, or 0.39¢/mg/L of absorbed ozone dose, generated in air (electricity cost: 3.1¢/kWh).

Costs were estimated for treating the Dalton GA combined municipal/industrial wastewaters with ozone (at a dosage of 45 mg/l) and with granular activated carbon, to attain the specified color level in the treated waters (25). Pertinent data are given in Table 10.

EPA-287 (Cin.)
(4-76)

TABLE 10. PROJECTED COST DATA FOR TREATING DALTON, GA WASTEWATERS (25)

Cost Factor	Ozone	GAC
lbs/day required	4,500	780
total capital required	$1.85 MM	$11.2 MM
amortization (7%; 20 yrs.)	$237,860	$1.06 MM
annual operation & maintenance	$296,495	$29,893
total costs over 20 years	$10.7 MM	$21.8 MM

Assumptions: 45 mg/L of ozone required to attain color level
flow rate: 12 mgd
GAC cost: 50¢/lb; 5% lost on regeneration
GAC regeneration cost: 8¢/lb
ozone generation requires 11 kWh @ 1.5¢/kWh

The cost comparisons of Table 10 were made in early 1975. Since that time several major cost items have changed significantly. First, the amount of electrical energy required to generate one pound of ozone has dropped significantly. Ozone generation equipment for the two Indianapolis, IN plants was bid at 2.86 kWh/lb of ozone generated from oxygen (21). This figure is roughly equivalent to 5.72 kWh/lb of ozone generated from air, or about 50% of the cost estimated in 1975.

On the other hand, the cost of electricity has at least doubled in most areas of the country, as has the cost of virgin GAC, and probably the GAC thermal reactivation costs. In addition, amortization costs also have risen from the 7% estimated in 1975.

Nevertheless, it can be observed from the estimates of Table 10 that over the 20 year period, costs for ozonation effect overall savings when compared with those for GAC adsorption. Most of the difference lies in the much larger capital investment required for installing GAC, with attendant increase in annual amortization.

CONCLUSIONS

1) Use of ozone for treating combined municipal/industrial wastewaters is not extensive as yet. In the United States, ozonation has been designed into the treatment process at the Cleveland, Ohio Westerly plant prior to GAC adsorption and chlorine disinfection. The function of ozonation at Westerly is several-fold:

- oxidize high molecular weight organic material to lower molecular weights
- oxidize other organic materials (satisfy ozone demand), rendering them more readily biodegradable

- oxidize iron
- provide aerobic conditions in dual media filters & GAC adsorbers
- increase operating lifetime of GAC adsorbers before reactivation

2) Ozone is being used on full scale in United States municipal wastewater treatment plants, primarily for disinfection, at 11 currently operational plants. Another 23 plants are under construction and an additional 5 are in design, all of which will incorporate ozone treatment.

3) Disinfection of secondary treated and filtered wastewaters with ozone can attain a fecal coliform level of 200/100 mL at 4 to 8 mg/L absorbed ozone dosages.

4) If wastewaters contain significant amounts of industrial wastes, the ozone demands to attain comparable disinfection can increase from 4-8 mg/l to as high as 15 mg/L.

5) The more stringent disinfection level of 2.2 total coliforms/100 mL can be attained with absorbed ozone dosages of 15 to 20 mg/L (filtered nitrified secondary effluents) or 35 to 40 mg/L (filtered secondary effluents).

6) Ozone treatment of Dalton, GA combined municipal/industrial wastewater (90% from carpet producing plants) on pilot plant scale was shown to be more cost-effective than GAC adsorption for color removal over a 20 year period.

7) Ozonized wastewaters have not shown toxic effects to indigenous aquatic species.

8) Costs of ozone treatment of wastewaters range from 1.5¢ to 2.2¢ per mg/L of absorbed ozone dose at plant sizes of 1.5 mgd and 0.86¢ per mg/L of absorbed ozone dose and below at 10 mgd plant sizes. These costs are based on performance data at operating pilot plant and full-scale plants generating ozone from air.

REFERENCES

1. Miller, G.W., R.G. Rice, C.M. Robson, R. Scullin, H. Wolf & W. Kühn. An Assessment of Ozone and Chlorine Dioxide Technologies for Treatment of Municipal Water Supplies. EPA Report No. 600/2-78-147, U.S. Environmental Protection Agency, Cincinnati, Ohio, 1978. 571 pp.

2. Rice, R.G., C.M. Robson, G.W. Miller & A.G. Hill. Practical Uses of Ozone in Drinking Water Treatment. In: Oxidation Techniques in Drinking Water Treatment, Drinking Water Pilot Project, Report IIA, Advanced Treatment Technology, Karlsruhe, Federal Republic of Germany, 1979. EPA Report 570/9-79-020, U.S. Environmental Protection Agency, Office of Drinking Water, Washington, D.C., 1979. pp. 418-450.

3. Brungs, W.A., Effect of Residual Chlorine on Aquatic Life. J. Water Poll. Control Fed. 45:2180-2193, 1973.

4. Venosa, A.D. & E.J. Opatken, Ozone Disinfection - State of the Art. Presented at Pre-Conference Workshop on Wastewater Disinfection, 52nd Annual Water Pollution Control Federation Conf., Houston, Texas, Oct. 7, 1979.

5. Stover, E.L. & R.N. Jarnis, Obtaining High Level Wastewater Disinfection With Ozone: Water Quality Considerations. Presented at 52nd Annual Water Pollution Control Federation Conf., Houston, Texas, Oct. 1979.

6. Wynn, C.S., B.S. Kirk & R. McNabney. Pilot Plant for Tertiary Treatment of Wastewater With Ozone. EPA Report No. R2-73-146, U.S. Environmental Protection Agency, Washington, D.C., 1973. 231 pp.

7. Nebel, C., R.D. Gottschling, R.L. Hutchinson, T.J. McBride, D.M. Taylor, J.L. Pavoni, M.E. Tittlebaum, H.E. Spencer & M. Fleischmann. Ozone Disinfection of Industrial-Municipal Secondary Effluents. J. Water Poll. Control Fed. 45:2493, 1973.

8. Rosen, H.M., F.E. Lowther & R.G. Clark. Disinfection of Municipal Secondary-Tertiary Effluents With Ozone: Five Recent Pilot Plant Studies. In: Proc. First Intl. Symposium on Ozone for Water & Wastewater Treatment, Washington, D.C. Intl. Ozone Assoc., Cleveland, Ohio, 1975, pp. 425-435.

9. Rice, R.G. & M.E. Browning, Editors. Proc. First Intl. Symposium on Ozone for Water & Wastewater Treatment, Washington, D.C. Intl. Ozone Assoc., Cleveland, Ohio, 1975. 910 pp.

10. Rice, R.G., P. Pichet & M.A. Vincent, Editors. Proc. Sec. Intl. Symposium on Ozone Technology, Montreal, Canada. Intl. Ozone Assoc., Cleveland, Ohio, 1976. 727 pp.

11. Fochtman, E.G., R.G. Rice & M.E. Browning, Editors. Forum on Ozone Technology, Chicago, Ill. Intl. Ozone Assoc., Cleveland, Ohio, 1977. 435 pp.

12. Blogoslawski, W.J. & R.G. Rice, Editors. Aquatic Applications of Ozone, Boston, Mass. Intl. Ozone Assoc., Cleveland, Ohio, 1975. 226 pp.

13. Novak, F. Two Years of Ozone Disinfection of Wastewater at Indiantown, Florida. Presented at Seminar on Current Status of Wastewater Treatment and Disinfection With Ozone, Cincinnati, Ohio, Sept. 1977. Intl. Ozone Assoc., Cleveland, Ohio.

14. Rice, R.G. & M.E. Browning. Ozone For Industrial Water and Wastewater Treatment, A Literature Survey. Final Report, EPA Grant No. R-803357, _in press_. U.S. Environmental Protection Agency, Ada, Oklahoma, 1980.

15. Rakness, K.L. & B.A. Hegg. Full Scale Ozone Disinfection of Wastewater at the Upper Thompson Sanitation District AWT Facility. Presented at

EPA-287 (Cin.)
(4-76)

Pre-Conference Workshop on Wastewater Disinfection, 52nd Annual Water Pollution Control Federation Conf., Houston, Texas, Oct. 7, 1979.

16. Jain, J.S., N.L. Presecan & M. Fitas. Field-Scale Evaluation of Wastewater Disinfection by Ozone Generated From Oxygen. In: Proc. Natl. Symposium on Progress in Wastewater Disinfection Technology, Cincinnati, Ohio, Sept. 18-20, 1978. EPA Report 600/9-79-018, U.S. Environmental Protection Agency, Cincinnati, Ohio, 1979. pp. 198-209.

17. Grissom, C.F. Planning Decisions in Selecting Wastewater Effluent Disinfection for the Olentangy Environmental Control Center. In: Proc. Natl. Symposium on Progress in Wastewater Disinfection Technology, _op. cit._, pp. 258-262.

18. Sproul, O.J., C.E. Buck, M.A. Emerson, D. Boyce, D. Walsh & D. Howser. Effect of Particulates on Ozone Disinfection of Bacteria and Viruses in Water. EPA Report No. 600/2-79-089, U.S. Environmental Protection Agency, Cincinnati, Ohio, 1979. 76 pp.

19. Hoff, J.C. The Relationship of Turbidity to Disinfection of Potable Water. In: Evaluation of the Microbiology Standards for Drinking Water, C. Hendricks, Ed., EPA Report 570/9-78-00C, 1978.

20. Bhargava, P. Ozone Disinfection of Pure Oxygen Activated Sludge Using Unique Partial Recycle System. Presented at 52nd Annual Conference, Water Pollution Control Federation, Houston, Texas, Oct. 1979.

21. Robson, C.M., Dept. of Public Works, City of Indianapolis, Indiana, 1980. Private Communication.

22. Shifrin, W.G. & P.F. Johnson. Ozonation Takes a Giant Step. Water & Wastes Engineering, March 1978. pp. 50-53. Also, Shifrin, W.G., Consoer, Townsend & Associates Ltd., Consulting Engineers, Chicago, Ill., 1980. Private Communication.

23. Horsley, E., C.M. Robson & R.E. Riemer. Wastewater Ozonation at Indianapolis, Indiana. Presented at Symposium on Advanced Ozone Technology, Toronto, Ontario, Canada, Nov. 1977. Intl. Ozone Assoc., Cleveland, Ohio.

24. Allen, R.K. & V.C. Oblas. Plant to Disinfect Wastewater With Ozone. Water & Sewage Works, July, 1978. pp. 48-53.

25. Nebel, C. & L. Stuber. Ozone Decolorization of Secondary Dye-Laden Effluents. In: Proc. Sec. Intl. Symp. on Ozone Technology, Montreal, Canada, 1975. Intl. Ozone Assoc., Cleveland, Ohio, 1976. pp. 336-358.

26. Ward, R.W., R.D. Griffin & G.M. DeGraeve. Disinfection Efficiency and Residual Toxicity of Several Wastewater Disinfectants. Vol. II - Wyoming, Michigan. EPA Report No. 600/2-77-203, U.S. Environmental Protection Agency, Cincinnati, Ohio, 1977. 107 pp.

27. Guirguis, W.A., T. Cooper, J. Harris & A. Ungar. Improved Performance of Activated Carbon by Pre-Ozonation. J. Water Poll. Control Fed. 50(2):308-320, 1978.

28. Hanna, Y.A. Application of Ozone as a Carbon Pretreatment Step at Cleveland's Westerly Plant. Presented at Seminar on Current Status of Wastewater Treatment & Disinfection with Ozone, Cincinnati, Ohio, Sept. 15, 1977. Intl. Ozone Assoc., Cleveland, Ohio.

29. Jenks, J.H. & B.L. Harrison. Multi-Feature Reclamation Project Accomplishes Multi-Objectives. Water & Wastes Engineering, Nov. 1977.

30. Perrich, J.R. & D.G. Derrick. Design Philosophy for an Ozonation Wastewater Disinfection System. Presented at 51st Natl. Water Pollution Control Federation Conference, Anaheim, Calif., Oct. 4, 1978.

31. Chambers, C.C. U.S. Environmental Protection Agency, Cincinnati, Ohio, 1972. Private Communication.

32. Pavoni, J.L., M.W. Tenney, M.E. Tittlebaum, B.F. Maloy & T.L. Kochert. The Consultant's Viewpoint on Alternate Disinfectants. In: Proc. Natl. Symposium on Progress in Wastewater Disinfection Technology, op. cit., pp. 263-268.

33. Guirguis, W.A., J.P. Harris & P.B. Melnyk. The Negative Impact of Industrial Waste on Physical-Chemical Treatment. In: Proc. 31st Indl. Waste Conf., Purdue Univ., Lafayette, Ind., May4-6, 1979. Ann Arbor Science Publishers Inc., Ann Arbor, Mich. pp. 753-763.

34. Rakness, K.L. & B.A. Hegg. Field Scale Evaluation of Wastewater Disinfection by Ozone Generated From Air. In: Proc. Natl. Symposium on Progress in Wastewater Disinfection Technology, op. cit., pp. 174-197.

35. LePage, W.L. A Plant Operator's View of Ozonation. In: Proc. Seminar on The Design and Operation of Drinking Water Facilities Using Ozone or Chlorine Dioxide, Waltham, Mass., June 4-5, 1979. New England Water Works Assoc., Dedham, Mass.

THE USE OF SOLAR ENERGY FOR COMBINED MUNICIPAL-INDUSTRIAL WASTEWATER TREATMENT

A. J. Acher*
Utah Water Research Laboratory
Utah State University
Logan, UT 84322

ABSTRACT

The material presented represents three years of ongoing research on a new method for using solar energy for municipal and industrial wastewater treatment. This research seeks to develop economical methods of disinfection and detoxification of wastewaters which would result in the reuse of effluents for crop irrigation.

Aerated municipal or industrial wastewaters containing dye-sensitizers were exposed to solar irradiation for various periods of time. The influence of the solar energy, absorbed by these sensitizers in the visible range, on the organic matter and anionic surfactants in secondary effluents was checked by determining the COD and MBAS values of treated wastewater.

The disinfection potential of this method was followed by bacteriological analyses of running water or secondary effluents, previously contaminated or enriched, respectively, with laboratory cultures of *E. coli*, bacteriophages (coliphage X and F_2) and polio virus (type L-Sc 1).

The influence of this photooxidative method was also studied on eutrophic algae present in the Lake of Galilee. It was found that the conditions under which disinfection proceeds also support algicidal processes, causing lethal damage to algal cultures.

Further investigations on stable pesticides (uracil derivatives) in surface water or industrial wastewater showed that such a method can also be used for detoxifying pesticides in these waters.

INTRODUCTION

The reuse of effluents for crop irrigation requires that they not constitute any ecological hazard for people working in the irrigated fields or handling and consuming the agricultural products, or for crop growth and soil properties. Such a requirement can be fulfilled by disinfection and detoxification of the wastewater effluents.

---

*On sabbatical leave from the Volcani Center, Institute of Soils and Water, Bet Dagan, Israel.

The material presented represents three years of a multidisciplinary ongoing research effort on a new method for using solar energy for municipal and industrial wastewater treatment. It deals with the influence of sunlight irradiation on sensitized waters containing different organic pollutants such as: bichromate oxidizable organic matter (COD), anionic surfactants (MBAS), microorganisms (*E. coli*, algae, polio virus, bacteriophages) and phytotoxic organic substances (pesticides).

Dye-Sensitized Photooxidation Reactions

These chemical reactions are responsible for the oxidative processes which take place in surface waters exposed to solar radiation. They consist of the combined action of visible light and molecular oxygen (O_2) dissolved in water upon organic matter (OM) through the intermediary of an appropriate photosensitizer (S). The S (methylene blue, rose bengal, chlorophyll riboflavin, humic acid, fulvic acid, etc.) is an organic molecule having a special electronic structure which enables it to absorb, and then to transfer, some of the light radiated energy. The S is added to the aerated and light exposed effluents and its absorbed energy (S^*) is made available to the oxidation of OM. Either one or both of the following mechanisms can operate in aerobic photosensitized oxidations (1):

1. Primary interaction of the electronically excited S^* is with OM to generate reactive, short-lived intermediates which subsequently react with O_2:

$$S + h\nu \rightarrow S^* \qquad \text{(i)}$$

$$S^* + \text{OM} \rightarrow \text{transient specia} \xrightarrow{+O_2} \text{oxidation products} + S \qquad \text{(ii)}$$

(transient specia = free radicals, ion pairs, etc.)

2. The presence of O_2 will compete successfully with OM on receiving the excitation energy from S^*. The addition of this energy to O_2 changes its ground electronic state (triplet state, ${}^3\Sigma g O_2$) to the first excited singlet state (${}^1\Delta g O_2$) which has a higher energy by 22.5 kcalmole^{-1}. When more energy is imparted to O_2, another electronic state is formed (${}^1\Sigma g O_2$) which corresponds to a level of 37.5 kcalmole^{-1} above the ${}^3\Sigma g O_2$. From the properties of singlet oxygen (exceedingly short lifetimes of ${}^1\Sigma g O_2$) it seems likely that only ${}^1\Delta g O_2$ is important in solution photooxidations:

$$S^* + {}^3\Sigma g O_2 \rightarrow S + {}^1\Delta g O_2 \qquad \text{(iii)}$$

$${}^1\Delta g O_2 + \text{OM} \rightarrow \text{oxidation products} \qquad \text{(iv)}$$

In both mechanisms the sensitizer is regenerated and undergoes hundreds of cycles so that only minute amounts of it are required.

In view of the diversity of OM present in wastewaters, it is very difficult to decide which mechanism operates in the present process. The presence of singlet oxygen in natural waters was proven a few years ago (2) and it is well known that it oxidizes unsaturated organic compounds (UC) to peroxides. The subsequent thermal and photochemical decomposition of these peroxides can further initiate free radical oxidation reactions which will also affect saturated compounds (R'H) found in wastewaters:

$$^1\Delta g O_2 + UC \rightarrow ROOR \rightarrow 2RO\bullet \qquad \text{(v)}$$

$$RO\bullet + R'H \rightarrow ROH + R'\bullet \qquad \text{(vi)}$$

$$R'\bullet + O_2 \rightarrow ROO\bullet, \text{ etc.} \qquad \text{(vii)}$$

As a result of the above reactions, vital biological components (proteins, lipids, polysaccharides) undergo oxidative degradations and, consequently, biological development in the treated waters is inhibited. Such photosensitized reactions, also referred to as "photodynamic action," were known a long time ago (3-5) and have been extensively studied with regard to their use in laboratory syntheses or oxidative degradation of various naturally occurring and synthetic substances. This research overlooks the possibilities of using sunlight and the above reactions for developing new methods of purifying wastewaters which eventually will be reused for crop irrigation.

RESULTS AND DISCUSSION

The effect of sunlight irradiation on waters containing sensitizers and different organic pollutants will be presented and discussed.

The Effect of Photochemical Treatment of Waters on COD and MBAS Values

Samples of effluents of circulated oxidation ponds of municipal sewage containing methylene blue (MB) were exposed to sunlight in graduated glass cylinders (250 mℓ) under continuous aeration (6). After the exposure, the MB was removed from the effluent by precipitation with bentonite clay (B), employing a ratio of 8:1, B:MB. The supernatants were analyzed for chemical oxygen demand (COD) and methylene blue active substances (MBAS) content and compared to blank experiments. Figure 1 shows the effect of MB concentration on COD and MBAS values after 6 h of irradiation at $1950 \pm 50 \mu Em^{-2}s^{-1}$. The best results were obtained at a concentration of 12 mg $MB\ell^{-1}$. At this concentration and 6 h of irradiation, the initial COD and MBAS values were reduced by more than 70 percent and 90 percent, respectively. The reason why concentrations below 10 mg $MB\ell^{-1}$ were less effective was the very poor effluent quality which removed some of the dissolved MB by physical and chemical reactions (6). Higher concentrations than 15 mg $MB\ell^{-1}$ decrease the light penetration into a darker medium, decreasing the effectiveness of the photooxidation process.

The effect of the radiation time on the COD and MBAS values of the effluents is shown in Table 1. The fact that COD values remained practically unchanged after 6 h of irradiation proved the presence of OM which were probably refractory to photooxidation. The methylene blue active substances

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

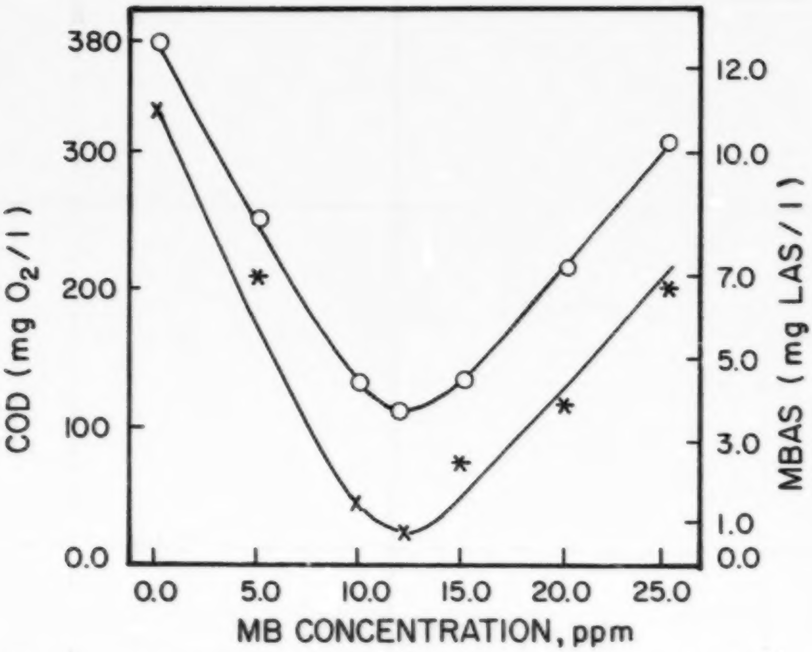


Figure 1. The effect of MB concentration on COD (°) and MBAS (*) values.

TABLE 1. THE EFFECT OF RADIATION TIME ON THE COD AND MBAS VALUES OF THE EFFLUENTS*

Radiation Time (h)	COD (mg O_2/ℓ)	MBAS (mg LAS/ℓ)
0.0	460	11.3
0.5	360	7.8
1.0	290	6.3
2.0	240	4.6
4.0	160	2.1
6.0	130	1.6
8.0	125	1.3
10.0	125	1.1

* Working conditions: 12 mg MB/ℓ; 32±2°C; 1980±60 $\mu Em^{-2}s^{-1}$. Blank in dark after 10 h: COD, 380, MBAS, 9.8.

were much more sensitive to the irradiation time and continued to be degraded after 6 h, remaining less than 10 percent of their initial value (11.3 mgℓ^{-1}) after 10 h.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS

EPA-287 (Cin.) (4-80)

The Effect of the Photochemical Treatment of Waters on Microorganisms

Laboratory Experiments with *Escherichia coli*

Samples of tap water and municipal effluents, to which an innoculum of fecal *E. coli* had been added, were exposed to solar irradiation in graduated glass cylinders (100 mℓ) in the presence of MB or rose bengal (RB), under continuous aeration (7). Table 2 shows the effect of MB concentration on survival of the coliforms after 28 min of irradiation (sunlight intensity: 2,030 $\mu Em^{-2}s^{-1}$; temperature: 32±2°C).

TABLE 2. THE EFFECT OF MB CONCENTRATION ON THE DESTRUCTION OF COLIFORMS*

MB Concentration (mg/ℓ)	Viable Coliforms (MPN/100 mℓ) Sewage	Tap Water
0.00	5.6×10^8	7.5×10^8
0.25	-	4.8×10^3
0.50	2.9×10^4	4.0×10^3
1.00	9.5×10^3	2.1×10^3
2.00	1.1×10^3	2.0×10^3
4.00	-	<20
5.00	<20	-

* Initial coliform density: sewage 1.3×10^9, inoculated tap water 9.2×10^8

The bactericidal effect was obtained by destructive photooxidation and was not a mere dye-sensitizer inhibition of coliform growth (7). Almost the same results were obtained by another group of researchers (8).

The effect of sunlight intensity and exposure time on the coliforms' survival in effluent samples containing 2 $mgMB\ell^{-1}$ is shown in Table 3 (the initial coliform count: 1.3×10^9 MPN/100mℓ; temperature: 32±3°C).

The data presented in Table 3 show the existence of interraction among dye concentration, length of exposure, intensity of irradiation, and coliform destruction. One of the most important conclusions regarding this data is that the intensity of solar radiation may not be a limiting factor, when disinfection of waters by sensitized photooxidation is considered. As far as the destruction of coliforms in sewage effluents is concerned, the results obtained by this method appear to be much more satisfactory than those reported for chlorination (9).

The Effect of Photochemical Treatment of Waters on Algal Growth

A study was carried out to determine the effects of various concentrations of MB and RB at different sunlight exposure times on the reduction of

TABLE 3. THE EFFECT OF SUNLIGHT INTENSITY AND EXPOSURE TIME ON THE DESTRUCTION OF COLIFORM IN SEWAGE*

Exposure Time (min)	Sunlight Radiation Intensity (μEm^{-2}s^{-1})	Sunlight Radiation Amount (Em^{-2})	Viable Coliforms (MPN/100 mℓ)
0	0	0	1.3×10^9
4	2,030	0.49	1.8×10^8
28	2,030	3.40	7.9×10^2
42	2,030	5.10	<20
40	68	0.16	1.7×10^4
120	68	0.49	7.9×10^2
150	68	0.61	<20

* Control sample after 150 min incubation in dark at 35°C had 1.1×10^9 coliforms/100 mℓ.

the algae population (10). The behavior of three algae from the Lake of Galilee (Israel) were studied in batch cultures: the dinoflagellate *Peridinium cinctum fa westii* and two chlorophyta algae, *Pediastrum duplex* and *Cosmarium* sp. The algae were grown in a minimal artificial medium and an alternating light cycle (10). Table 4 shows the synergistic effect of solar exposure and the sensitizer on algal growth. These results suggested that the algae investigated are sensitive to sensitized photooxidation and may undergo lethal damage; they might be useful for treatment of industrial or municipal wastewaters containing pollutants which favor algal development. The effect of the sensitizer's presence in the culture medium on algal growth is shown in Figures 2, 3, and 4. These figures and Table 4 demonstrate that the sensitized photooxidation is adequate also for algal destruction, without suffering from the drawbacks of the conventional method (10). Furthermore, as the dye-sensitizers are eventually photooxidized to uncolored compounds, no detrimental environmental impact is to be expected.

The Effect of the Photochemical Treatment of Effluent in a Pilot Plant Scale Experiment

The effluent of a municipal sewage oxidation pond, having about the same main characteristics as were used in previous studies (6), was pumped into an open, epoxy-coated steel reactor (Figure 5). A solution of MB was continuously added into the effluent (2 g MB/m^3 effluent) in a mixing container connected directly to the reactor. When the effluent depth reached 25 cm (about 2.5 m^3), the suction from the oxidation pond was stopped and the pump switched to recirculate the treated effluent. The effluent was contaminated with laboratory cultures of bacteriophages (coliphage X and F2), polio virus type 1-L Sc (vaccine strain). Samples taken at different times were bacteriologically analyzed. The results showed that those bacteriophages which were resistent to chlorination (up to

TABLE 4. THE MINIMUM CONDITIONS FOR TOTAL ALGAL DESTRUCTION

Algae	Dye Type	Dye mg/ℓ	Solar Exposure (min)	Incubation Time (days)*
Pediastrum	MB	0.40	0	7
	MB	0.15	40	10
	RB	1.50	0	7
	RB	0.80	40	10
Cosmarium	MB	0.75	0	20
	MB	0.75	30	10
	RB	1.20	0	10
	RB	0.80	60	10
Peridinium	MB	0.50	0	25
	MB	0.25	30	14
	RB	2.00	0	35
	RB	0.60	30	35
Peridinium (in lake water)	MB	0.50	0	14
	MB	0.30	60	14
	RB	1.60	0	14
	RB	0.80	60	14

* Minimum incubation time when algal population count was zero, without subsequent recovery.

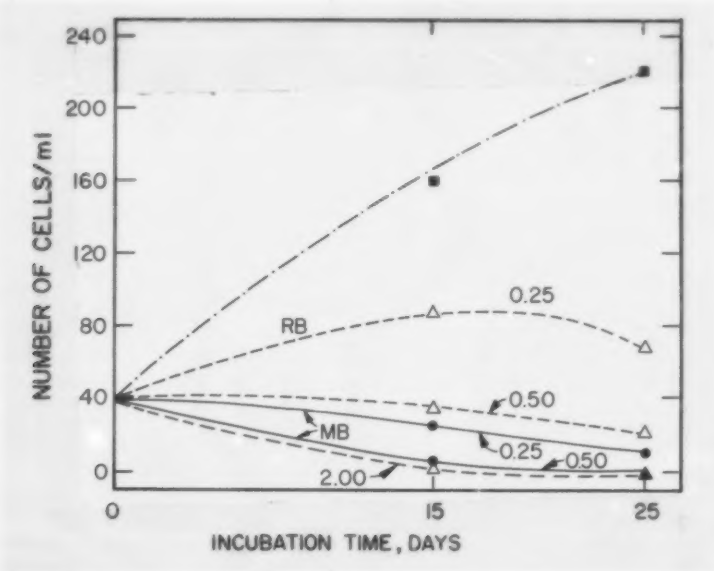


Figure 2. The effect of dye (ppm) on *Peridinium*.

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
DROPPED HEAD BEGIN SECTIONS HERE
CENTER OF PAGE
TOP OF IMAGE AREA

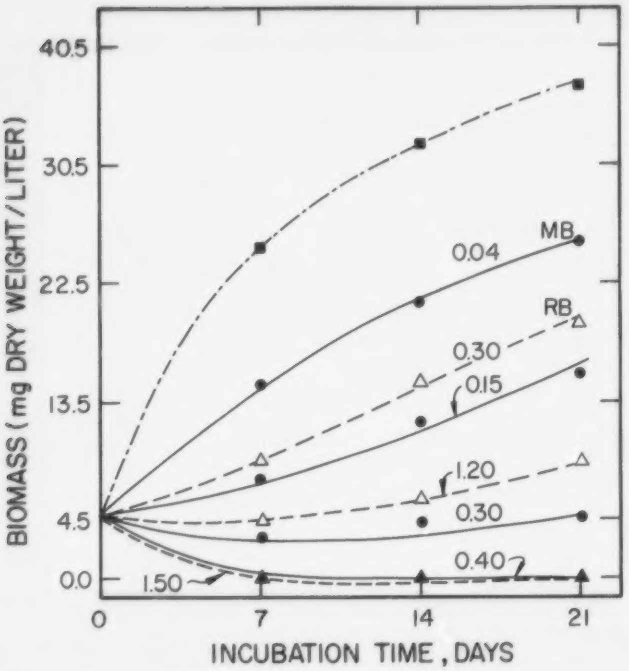


Figure 3. The effect of dye (ppm) on *Cosmarium*.

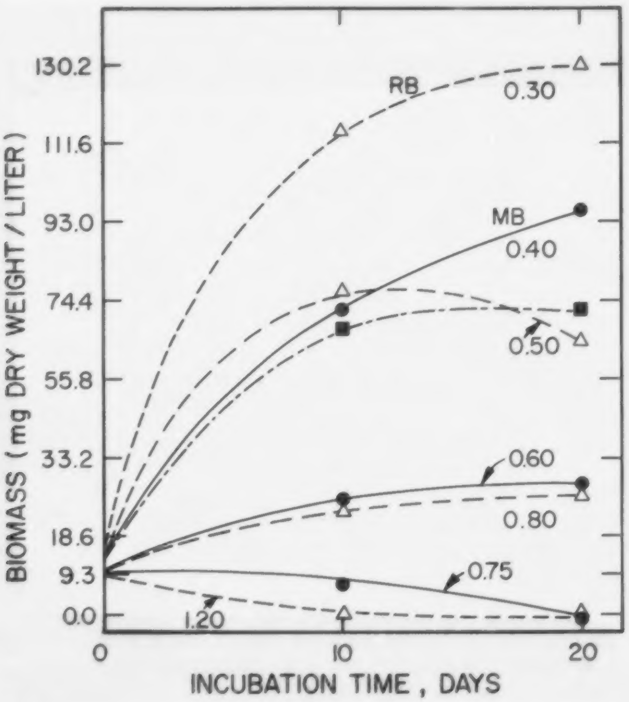


Figure 4. The effect of dye (ppm) on *Pediastrum*.

BEGIN LAST LINE OF TEXT
MAXIMUM IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS

PAGE
EPA-287 (Cin)

TABLE 5. RELATIVE SENSITIZING EFFECT

Sensitizer	Concentration (ppm)	pH 6.8	 9.2
Riboflavin	10	1.00	1.00
Methylene Blue	5	0.74	1.11
Rose Bengal	5	0.32	0.85
Humic Acid-a	20	0.06	0.20
Humic Acid-b	20	0.03	0.08

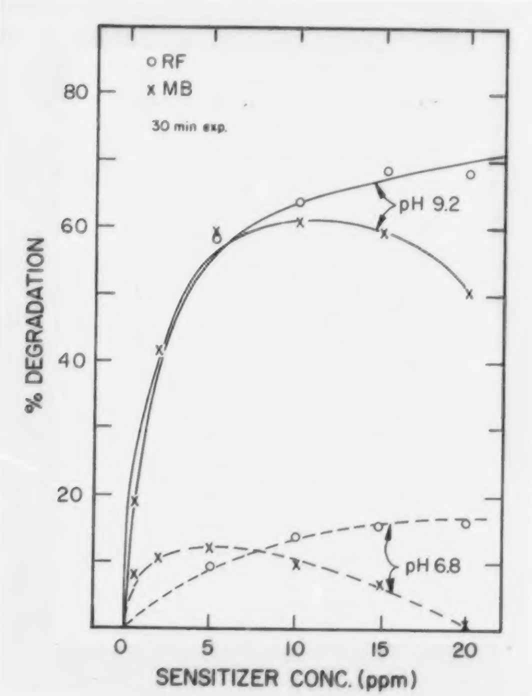


Figure 6. Bromacil photodecomposition.

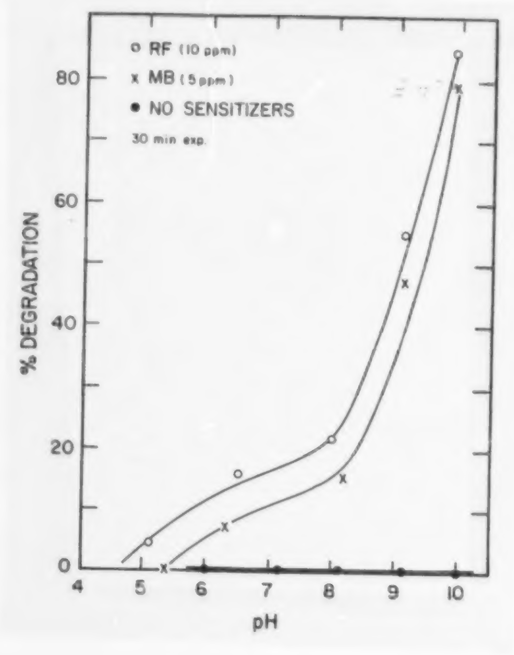


Figure 7. Bromacil photodecomposition

Sensitized Photooxidation of Terbacil in Water

Sunlight irradiation of an aerated terbacil (3-*t*-butyl-5-chloro-6-methyluracil) aqueous solution (700 mg/ℓ) in the presence of different sensitizers, at pH range from 4.0 to 9.2, led to its complete decomposition (14). Figures 8 and 9 show the photodecomposition of terbacil in the presence of MB and RF, respectively, as affected by pH (and temperature for MB case).

In the case of both bromacil and terbacil, sunlight irradiation of the sensitized solution of these herbicides causes decomposition and under optimum conditions no trace of them can be found after a few hours of this treatment. The intermediary products formed in these processes were isolated and identified (14, 15). Submitting industrial wastes containing these herbicides to the same photodecomposition procedure also resulted in a complete destruction of their phytotoxic properties (16).

The high inorganic salts content of the industrial wastes did not affect the photochemical process. The treated waters and the solution of photooxidation intermediary products were analyzed for their phytotoxicity. Bioassays were carried out using these waters and solutions to irrigate sensitive plants in their different stages of development. The results were completely satisfactory (17).

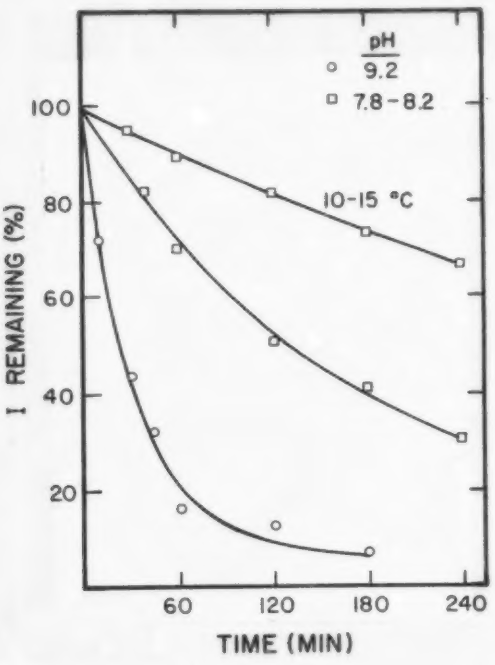


Figure 8. Terbacil MB photodecomposition.

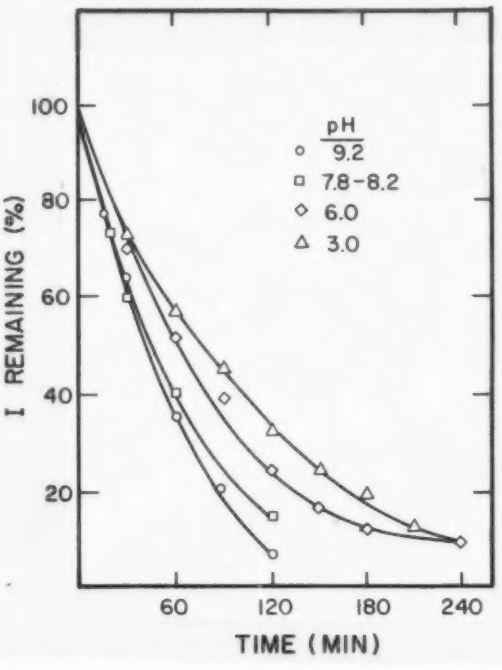


Figure 9. Terbacil RF photodecomposition.

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

CONCLUSIONS

A new approach of oxidation of organic pollutants in municipal and industrial effluents proposes the use of MB as a photosensitizer, air as the oxygen source, and sunlight energy as the photooxidation inducer. This approach is especially attractive in arid and semiarid zones where the climate is favorable for the promotion of photooxidation. In such zones there is also an acute need for water and this method seems to be cost effective and also to respond to the water requirements for crop irrigation. Of course, much more work has to be done in order to transform this new approach into a practical method.

ACKNOWLEDGMENTS

The multidisciplinary subjects treated in this study necessitated the cooperation of scientists with a wide variety of backgrounds. Their efficient collaboration is gratefully acknowledged: Dr. I. Rosenthal (photochemistry), Dr. B. Juven (bacteriology), Dr. A. Elgavish (algae metabolism), Dr. J. Marzouk (virology), Dr. S. Saltzman (soil chemistry), Dr. E. Dunkelblum (organic chemistry), and Dr. M. Horovitz (plant physiology).

REFERENCES

1. Kautsky, H. Quenching of luminescence by oxygen. Trans. Farad. Soc., 35:216-219, 1939.
2. Zepp, R. G., G. L. Baughman, N. L. Wolfe, and R. C. Hollis. Singlet oxygen in natural waters. Nature, Lond., 267:421-423, 1977.
3. Gollnick, K. Type II photo-oxygenation reactions in solution. Adv. Photochem., 6:1-122, 1968.
4. Kearns, D. R. Physical and chemical properties of singlet molecular oxygen. Chem. Rev., 71:395-427, 1971.
5. Foote, C. S. Mechanism of photosensitized oxidation. Science, 162: 963-970, 1968.
6. Acher, A. J., and I Rosenthal. Dye-sensitized photo-oxidation -- a new approach to the treatment of organic matter in sewage effluents. Water Res., 11:557-562, 1977.
7. Acher, A. J., and B. I. Juven. Destruction of the fecal coliform in sewage water by dye-sensitized photooxidation. Appl. Environ. Microbiol., 33(5):1019-1022, 1977.
8. Gerba, C. P., C. Wallis, and J. L. Melnick. Disinfection of waste water by photodynamic action. J. Water Poll. Control Fed., 49(4): 578-583, 1977.
9. Kott, Y. Hazards associated with the use of chlorinated oxidation pond effluents for irrigation. Water Res., 7:853-862, 1973.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD, BEGIN SECTIONS HERE

10. Acher, A. J., and A. Elgavish. The effect of photochemical treatment of water on algal growth. Water Res., 14(3): in press, 1980.

11. Acher, A. J., J. Marzouk, and J. Manor. Disinfection of effluents by a photochemical treatment -- Pilot plant experiments. Progress report to Israeli Council for R&D, Jerusalem (Nov. 1979, in Hebrew).

12. Moilanen, K. W., and D. G. Crosby. The photodecomposition of bromacil. Arch. Environ. Contam. and Toxic., 2:3-8, 1974.

13. Acher, A. J., and S. Saltzman. Dye-sensitized photodecomposition of bromacil in water. J. Environ. Qual., 9(1): in press, 1980.

14. Acher, A. J., S. Saltzman, N. Brates, and E. Dunkelblum. Photosensitized decomposition of Terbacil in aqueous solutions. J. Agric. Food Chem., 28(4): in press, 1980.

15. Acher, A. J., and E. Dunkelblum. Identification of bromacil photodecomposition products. J. Agric. Food Chem., 27(6):1164-1167, 1979.

16. Acher, A. J. A method for decomposing herbicidal residues in solutions. Israel Pat. Appl. 58495 (19 Oc., 1979).

17. Acher, A. J., S. Saltzman, and M. Horowitz. Sunlight induced detoxification of herbicides in water. Progress Report to Volcani Institute. 1980.

6-1/2"
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

PB83-142273

LAND TREATMENT OF COMBINED MUNICIPAL/INDUSTRIAL WASTEWATERS

C. E. Pound, Vice President
R. W. Crites, Project Manager
Metcalf & Eddy, Inc.
290 North D Street, Suite 505
San Bernardino, California 92401

ABSTRACT

The most direct measure of benefits from land treatment of municipal/industrial wastewaters is a cost comparison. Two case studies are presented which illustrate several ways that land treatment can be used to provide cost effective solutions to municipal/industrial wastewater management. Selection by one city of a separate but publicly owned land treatment system for industrial wastes resulted in reductions in cost from \$1.10/1,000 gal to \$0.35/1,000 gal for the industrial waste contributions. Selection by another city of a combined municipal/industrial land treatment resulted in reducing costs for one example industry from \$1.70/1,000 gal to \$1.12/1,000 gal as compared to an activated sludge system. In the first case, both industrial and municipal systems were eligible for federal grant funding because the parallel approach was most cost effective. The municipal wastewater was treated to 40 mg/l BOD and the industrial wastewater was applied raw except for screening. In the second case, a single land treatment system was constructed as the most cost effective because the industrial waste flow was small compared to the total combined flow.

INTRODUCTION

With the introduction of the financing and revenue program guidelines promulgated pursuant to Public Law 92-500, industrial waste dischargers have been faced with the difficult decision to combine their wastes with the municipal discharger or to treat and dispose of their waste independently. Although the decision had to be faced prior to this time, the inclusion of equal allocation of cost and the industrial payback provision made the decision more critical. Prior to the passage of PL 92-500, it was not uncommon to find industrial dischargers paying substantially less per unit of waste contribution than that of the municipal resident because of political decisions made to favor industrial growth in the community. With these arbitrary choices removed from the municipality and industrial dischargers, the decision has been reduced to mainly one of economics.

Financial decisions are easily made when a balanced analysis of the facts can be presented. Until recently this balance was difficult to obtain. It was not uncommon ten years ago to find the industrial discharger with little or no real data on flows and biological oxygen demand (BOD) or suspended solids (SS) contributions to the local treatment plant. This often led to serious differences of opinion when it came to paying for treatment costs to the local municipality. Consequently, when the industrial discharger began to consider the possibility of an independent waste management operation, he was very often lacking basic design data. He may have understood the total volume of discharge over the operating season but had little or no comprehension of the diurnal variations in either quantity or quality of his waste flows. This deficiency compounded the difficulty of making decisions regarding the question of independent waste management.

As the industrial waste discharger searched for a means of managing and disposing of his wastewater independently, he sought the least complex, the most economical, and the most flexible system available. Where the industrial waste discharger was located in or near a rural environment, and where waste constituents were non-toxic and biodegradable, the option of land treatment was given serious consideration.

Industrial waste dischargers as used in the context of this paper, refer to those that have a relatively large flow rate in proportion to that of the associated municipality and relatively high concentrations of BOD and/or SS. Further, the industrial classifications include those that do not contain substantial quantities of toxic pollutants that would preclude their use on land treatment systems. In essence, these industries include the food and beverage industries.

The purpose of this paper is to present and discuss two examples of decisions made by industry and cities that have resulted in the use of land application for wastewater treatment. Both examples were taken from the authors' files and were selected to present different types of decisions.

POTENTIAL BENEFITS OF COMBINED LAND TREATMENT

In a discussion of benefits it is necessary to determine to whom the benefits will accrue, and as compared to what alternatives. Further, a discussion of benefits in a general context can be very misleading. Nevertheless, the following thoughts will be presented in view of these limitations.

The greatest incentive to combining the industrial waste discharge with the municipal waste flow is to permit "out of sight, out of mind" treatment. That is, that the problem can be passed along to others, at a price, and all of the management's energy can be directed at their primary function of producing a salable product. If the price for this service reaches a level where production costs approach an unprofitable level, this option ceases to be an incentive. Many industries arrived at this condition as the new revenue programs took effect across the country. This resulted in one of several actions:

EPA-287 (Cin.)
(4-76)

1. the industry closed down its operation and moved to a more profitable location,

2. converted from combined treatment with the municipal facility to an independent treatment and disposal system such as land treatment, or

3. took steps to influence the local community to adopt a more cost effective (relative to the industry) methods of treatment and disposal.

There are both benefits and drawbacks to the independent land treatment alternative. Benefits usually include reduced capital and operating costs, independent operation and investment of capital in their own land that has historically accrued in value in time. The drawbacks include the use of their own working capital, and the management energies involved in scheduling and managing the waste treatment and disposal facilities.

Conversion of the publicly owned treatment facilities to land treatment also include a set of benefits and drawbacks. Benefits to industry usually include provision of management and operation of the facilities by others and provision of capital funding on a no interest loan basis (even less if industrial cost recovery is abandoned). The drawbacks to industry may be relatively few unless there are disagreements between industry and the municipal officials.

If conversion of the publicly owned facility is made by separating the industrial waste system from the domestic system, the preceding benefits can be gained for industry plus additional benefits to both, such as:

1. Overall costs will be less, especially for industry, because the industrial waste stream could likely be applied to land without pretreatment.

2. The design and operation of that portion of the facility can be closer to optimum if the transient loads associated with large industrial waste dischargers are removed from the domestic waste flows.

3. Costs associated with disinfection of domestic wastes can be avoided for the industrial waste stream if separated from the domestic waste stream.

Each of these conditions may be seen in the following case examples.

EXAMPLE NO. 1

The first case involved a moderately sized community with two major food processing industries connected to the municipal wastewater system. During the three month canning season, industries A and B contribute 88% of the BOD and 79% of the SS in the combined wastewater. This peak loading required the preapplication treatment facilities to be overdesigned for the remaining nine months of the year when the industrial flows and loads are reduced to less than 20% of the combined flow and load. The average flows and loads are presented in Table 1.

TABLE 1 FLOWS AND LOADS FOR EXAMPLE 1

	Flow, mgd	BOD load, 1,000 lb/day	SS load, 1,000 lb/day
Canning season (7/15 - 10/15)			
Industry	7.3	39.1	28.1
Domestic	4.7	5.5	7.6
Total	12.0	44.6	35.7
Remainder of Year			
Industry	1.1	0.8	0.8
Domestic	4.7	5.5	7.6
Total	5.8	6.3	8.4

At the beginning of the facilities planning step, both industries were discharging to the treatment plant. The initially recommended alternative was to treat the combined municipal/industrial wastewater in aerated lagoons and then apply the effluent to crop land for irrigation. To apply the wastewater effluent to the land it was necessary, under existing requirements, to reduce the BOD from over 500 mg/L to less than 40 mg/L. The total annual cost of this alternative was $0.68/1,000 gallons.

The two industries were alarmed that their costs under this alternative would increase substantially over their previous costs to about $1.10/1,000 gal. They proposed that alternatives involving direct land treatment of the industrial wastewater be investigated. Two alternatives were developed that would offer savings both to the municipality and to the industries. These alternatives are summarized with their estimated costs in Table 2.

TABLE 2 WASTEWATER TREATMENT ALTERNATIVES FOR EXAMPLE 1

	Applied BOD, mg/L	Total Annual Costs, $/1,000 gal	Industrial Costs, $/1,000 gal
Alternative 1			
Separate cannery land application at municipal site	1,500	0.62	0.35
Alternative 2			
Separate cannery land application at individual sites near industries	1,500	0.69	0.68
Base			
Combined treatment and application	40	0.68	1.10

As indicated in Table 2, the alternatives did not produce significant reductions in the overall cost of the system for the combined municipality and industry. There are, however, significant savings for the industries in both Alternatives 1 and 2.

Industry A had some previous experience with land treatment and it studied a private land treatment system for comparison with the municipal alternatives. A private system was approximately the same cost as Alternative 1. The advantages of Alternative 1 were that:

1. The municipality would own and operate the system, and would provide the capital financing.
2. The alternative would be eligible for a full federal grant as the most cost effective plan for the municipality.

The advantages of the private land application system for Industry A were seen as follows:

1. Industry would have control of their own destiny and be able to reduce future treatment costs.
2. The land purchased would be an excellent investment.
3. A local farmer would manage the off-season farming operation and provide revenues to offset some of the operating costs.

EPA-287 (Cin.)
(4-76)

The appearance of a local farmer who was willing to operate the farm and manage the wastewater application was the deciding factor. Industry A decided to drop out of the municipal system and construct its own land treatment system.

Industry B, on the other hand, decided to remain in the municipal system. Their wastewater will be maintained separate from municipal wastewater and will be treated by the irrigation method of land treatment.

The municipality was therefore able to design a secondary treatment system for a wastewater with a relatively constant BOD. The system of preapplication treatment is also designed for a significantly smaller hydraulic capacity.

Each member of this decision trio was able to achieve the desired least cost treatment alternative using land treatment.

EXAMPLE NO. 2

This example involves a moderately large city in California that has one milk processing plant which operates continuously throughout the year. This industrial example will serve to illustrate the advantages of land treatment as compared to an activated sludge type of biological treatment followed by disinfection and discharge to a surface receiving water. Table 3 presents the flow and wastewater characteristics for both the example industry and the city as a whole.

TABLE 3 FLOWS AND LOADS FOR EXAMPLE 2

	Flow, mgd	BOD Load, lb/day	SS Load, lb/day
Industry alone*	0.152	2,360	1,180
Combined Municipal+	17.33	30,820	32,410
Plant Capacity+	22.50	46,900	51,400

* Only one of several industrial contributors.

+ Portions of flow treated at two different plant; 3.5 mgd and 19.0 mgd design capacities, respectively.

Initially, the concept was developed to treat the wastewater by biological treatment to permit discharge to a local irrigation canal. Use of a canal is required because there is no continuously flowing river nearby to receive the effluent. To permit discharge to the canal, the effluent quality would have to meet the relatively stringent BOD and SS standards of 20 mg/L. Further, as shown in Table 4, disinfection would be required to achieve a seven day mean value of 23 MPN/100 ml of total coliforms. In case there was less than a 1:1 dilution ratio in the canal, disinfection would be increased to 2.2 MPN/100 ml.

TABLE 4 DISCHARGE REQUIREMENTS FOR THE DIFFERENT TREATMENT ALTERNATIVES

Constituent	Surface Discharge	Crop Irrigation
BOD, mg/L	20	40
SS, mg/L	20	40
Total Coliforms, MPN/100 ml	23	--*

* Not stipulated, but fencing of farm lands is required to prevent public access.

Two alternative processes were evaluated for meeting the discharge standards: overland flow and conventional activated sludge. Estimated costs are presented for these alternatives in Table 5. Obviously, the costs estimated for the overland flow process are lower than the costs for the activated sludge process, but because the time schedule for compliance was short and the technology for overland flow treatment had not been applied on a scale of this size before that time (1974), the activated sludge alternative was approved for implementation. Although not shown, the economic analysis included selling the reclaimed water to an irrigation district, with revenues partially offsetting the higher costs of biological treatment provided by either activated sludge or overland flow, making these two alternatives the most cost effective. However, negotiations with the irrigation district broke down and the alternative of discharge to the canal system ceased to be economically viable.

The alternative finally adopted and implemented was biological treatment to 40 mg/L BOD in an aerated lagoon system followed by irrigation of farm lands. The costs for this alternative are also presented in Table 5.

TABLE 5 COMPARISON OF COSTS FOR ALTERNATIVE TREATMENT PROCESSES

Cost Item	Treatment Process Activated Sludge	 Overland Flow	 Irrigation
Capital Cost, $1,000*	20,270	13,960	24,590+
Operation & Maintenance Costs			
.Gross Annual O&M, $1,000	1,500	962	1,375
.Annual Revenues, $1,000	--	--	418
.Net Annual O&M, $1,000	1,500	962	957
Cost to the Industry, $/yr	94,360	58,000	62,100‡
, $/1,000 gal	1.70	1.04	1.12

* July 1977 Cost. Includes Steps 1, 2, and 3.

+ Includes $3,350,000 for land acquisition. This cost is based on actual contract prices. Others are estimated.

‡ Includes industrial cost recovery provisions.

A review of the annual costs to the industry for each alternative in Table 5 reveals an interesting circumstance. Biological treatment processes designed mainly for organic constituents will result in relatively high costs for high strength industrial wastes. Land treatment systems designed primarily around hydraulic parameters can result in the lowest costs for high strength industrial wastes. On the other hand, high flow rate, low strength wastes may result in disproportionately high costs for industry using a land treatment system

CONCLUSIONS

Because industries must make a profit on an ongoing basis, they must be sensitive to the cost of treating and disposing of their wastewaters. Sensitivity must involve consideration of total costs as well as relative costs. Costs must be similar to those of industries in other areas of the country. In any case, treatment costs should be as low as possible.

Land treatment, either as an independent operation or as a combined municipal/industrial operation, can help industries achieve the lowest possible treatment costs. Similarly, land treatment can permit municipalities to meet their treatment and disposal obligations at the least overall cost and simultaneously provide an industrial development incentive for their community.

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD, BEGIN SECTIONS HERE

PB83-142281

THE UTILIZATION OF SEWAGE SLUDGES ON CROPLAND

L. E. Sommers and D. W. Nelson
Agronomy Department
Purdue University
W. Lafayette, IN 47907

ABSTRACT

The application of sewage sludges on cropland is receiving increased emphasis because of environmental and economic constraints being placed on alternative disposal methods. Sewage sludges contain macronutrients (N, P, and K) and trace elements (e.g., Zn, Cu, Mn, B, and Mo) required for plant growth and thus, sewage sludges can be used as a low analysis fertilizer material. Numerous studies have indicated that comparable crop yields can be obtained by fertilizing soils with either sewage sludges or conventional inorganic fertilizer materials. However, sewage sludges also contain other constituents, primarily of industrial origin, which may limit their application rate on cropland. The sludge components of greatest concern include pathogens, slowly-degraded organics (e.g., PCB's) and non-essential heavy metals (Ni, Cd, and Pb). Approaches being developed for land application of sewage sludges are based on maintaining the productivity of agricultural cropland and the quality of the environment. Developing a land application system involves the following considerations: (1) pathogens; (2) nitrate and heavy metal leaching into groundwaters; (3) effects on human health resulting from Cd accumulation in crops; (4) phytoxicity due to increased soil levels of Cu, Zn, and Ni and; (5) contamination of crops with persistent organics such as PCB's. To minimize problems arising from pathogens, sludges applied to cropland are stabilized by anaerobic digestion or an equivalent process. Application techniques can be utilized to minimize accumulation of persistent organics on many crops. Limitations on annual applications of plant available N and Cd will minimize nitrate leaching and Cd uptake by crops, respectively. The life of a sludge application site is based upon the cumulative amounts of heavy metals added. It is particularly important that soil pH be maintained at 6.5 or above during and after sludge application to prevent phytoxicity from Cu, Zn, and Ni and to reduce plant uptake of Cd. This paper will emphasize the impact of sludge additions on soil and plant properties and the rationale used for developing a land application system.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

INTRODUCTION

One approach to solve the sewage sludge disposal problem faced by many municipalities and industries is the application of sludge on agricultural land. In addition to being an economical alternative, application of sewage sludges on cropland provides the growing crop with nearly all required macro- and micronutrients. In most cases, the concentrations of plant nutrients in sewage sludge are not present in the appropriate ratio and supplemental fertilization may be needed (e.g., K). However, sewage sludges commonly contain constituents which are potentially hazardous to plants or to animals or man after assimilation into crops. When considering application of sewage sludges on agricultural land, the sludge constituents of greatest concern are pathogens (human or animal), persistent organics (primarily chlorinated hydrocarbons), and heavy metals (e.g., Pb, Zn, Cu, Ni and Cd). The objectives of this paper are to evaluate the behavior of sludge components in soils and crops and to describe the procedures and considerations used in developing a system for application of sewage sludge on agricultural cropland.

BEHAVIOR OF SEWAGE SLUDGE COMPONENTS IN SOILS

Pathogens

The majority of sewage sludges applied to agricultural land are treated by a process to reduce the potential for dispersal of pathogens. Typical treatment processes include anaerobic or aerobic digestion, lime (CaO) treatment, extended storage in lagoons and composting. In spite of these stabilization practices, sludges typically contain coliform organisms, bacterial pathogens (Salmonella, Shigella), protozoa (Entamoeba), helminthic parasites (Ascaris) and viruses (1). Disease transmission could result from sludge applications which contaminate crops consumed raw by humans (e.g., vegetables), adhering to forages grazed by animals or entering surface or ground waters through runoff or leaching, respectively. In all cases, the ability of the organism to survive in soils or on plant surfaces is a prerequisite for the existence of a health problem.

The survival of selected pathogens that may be present in sewage sludges is shown in Table 1. The majority of bacteria can persist for time periods ranging from several days to 10 months in soils or on vegetation. Ascaris ova are capable of withstanding adverse environmental conditions in soil resulting in survival for periods up to 7 years. The survival of viruses in soils amended with sewage sludge has not been adequately evaluated but viruses have been isolated from soils for 8-13 days after sludge application (2, 3). Several factors influence the survival of pathogens in soils including temperature, moisture, pH, sunlight, toxic substances, competitive organisms, and nutrient supply (4). Studies on the survival of salmonellae in soils indicated a survival time of 7 days in dry soils at $39^{\circ}C$ (5). Survival was strongly influenced by interactions between soil moisture, temperature and inoculum carrier (waste or saline solution). Fecal califorms added to crops through wastewater irrigation are retained in the upper 8 cm of the soil and exhibit a 10% survival over 48 hrs. (6). In addition, 10 hours of bright sunlight completely eliminated fecal coliforms retained on alfalfa forage (7). The application of sludge to cropland has been shown to have minimal impact on the coliform and virus levels in both surface and ground waters (8). Except for Ascaris ova, the majority of sludge-borne pathogens will be at very low levels in soils amended with sludges after a one year period (1, 9).

Proper management of a sludge application site is essential to minimize any potential pathogene related problems. Sludge application guidelines are being developed by numerous states in addition to the U.S. EPA (10). The current recommendations to manage pathogens can be summarized as follows:

1. All sludges applied to soils growing human food-chain crops should be stabilized by a process which significantly reduces pathogens (i.e., aerobic or anaerobic digestion, lagooning, air-drying, heat-drying, composting, CaO treatment),

2. Stabilized sludges should not be applied to root or vegetable crops which can be consumed raw; root or vegetable crops can be grown on the site 18 mos. after sludge application,

3. Animals should not be grazed on pastures treated with sludge for one month after application.

Even though concern has been expressed about the addition of pathogens to soils in sludges, there has not been any significant widespread disease problems associated with land application of sludges.

Persistent Organic Compounds

Many sewage sludges contain organic compounds, primarily chlorinated hydrocarbons, which are relatively resistant to decomposition in soils and are of concern from a human health standpoint. The chlorinated hydrocarbon pesticides and the polychlorinated biphenyls are the principal sludge-borne compounds receiving attention. A recent survey has indicated that the majority of sewage sludges contain relatively low concentrations (<1 to 10 mg/kg) of these compounds although specific industrial inputs to the sewage system can result in elevated sludge levels (12). A recent survey of sludges produced in Indiana indicated that the median PCB concentration was 7 mg/kg (12) while sludges from Michigan typically contain <1 mg PCB's/kg (13). Since PCB's are no longer being widely used for industrial purposes, the concentration in sludges should decrease with time.

Both chlorinated hydrocarbon pesticides (14) and PCB's (15) are resistant to rapid degradation in soils. For PCB's, the rate and extent of degradation increases as the percentage chlorine in the compound decreases (16). Even though chlorinated organics persist in soils, they are not generally assimilated by plant roots and translocated to above ground parts such as the grain or fruit. In soils treated with 100 mg (PCB/kg, elevated concentrations were found in whole carrots (17). However, 97% of the PCB was located in carrot peelings suggesting that physical

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

Table 1. Survival of Selected Pathogens in Various Media.[a]

Organism	Media	Survival time, days
Coliforms	Soil Surface	38
	Vegetables	35
	Grass and Clover	6 - 34
Streptococci	Soil	35 - 63
Fecal streptococci	Soil	26 - 77
Salmonellae	Soil	15 - >280
	Vegetables and Fruits	3 - 49
	Grass and Clover	12 - >49
Shigellae	On Grass (Raw Sewage)	42
	Vegetables	2 - 10
Tubercle bacilli	Soil	>180
Vabrio cholerae	Vegetables and Fruit	<1 - 29
	Water and Sewage	5 - 32
Leptospira	Soil	15 - 43
Entamoeba histolytica cysts	Soil	6 - 8
	Vegetables	<1 - 3
Enteroviruses	Soil	8
	Vegetables	4 - 6
Ascaris ova	Soil	Up to 7 yrs.
	Vegetables and Fruits	27 - 35
Hookworm larvae	Soil	42

[a] Adapted from (1).

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

absorption to the root occurred rather than plant uptake. In addition, the carrot foliage did not contain detectable levels of PCB's. Similarly, essentially no plant uptake (orchardgrass and carrot foliage) has been found when polybrominated biphenyls are applied to soils (18). Since PCB's are somewhat volatile, application of sludge to the soil surface could result in absorption of volatilized PCB's by plant stems and leaves (19). This mechanism of plant contamination with PCB's can be eliminated by incorporating sludge into the upper 10 to 15 cm of soil.

The principal problem arising from chlorinated hydrocarbons is direct ingestion by grazing animals of surface-applied sludge adhering to forages. Research has indicated that sludge solids may constitute from 22 to 32% of the forage dry weight immediately following sludge application (19). The application of sludge to the stubble after mowing the forage resulted in less contamination. Dairy cattle are most susceptible to PCB contamination of forages because PCB's are readily partitioned into the milk fat. The allowable level of PCB's in animal feedstuffs is 0.2 mg/kg and thus, it is possible to calculate allowable PCB levels in sludge given a sludge application rate, forage yield, percent sludge retention on forages and an assimilation factor for the animal (21).

Based on the above considerations, the following recommendations are pertinent to managing PCB's and other persistent organics in land application systems:

1. Sludges containing >10 mg PCB/kg should be incorporated into the surface soil (0-20 cm),

2. Sludges should not be surface applied on forages grazed by dairy cattle. For other animals, forages can be grazed 30 days after application.

Heavy Metals

The heavy metals of most concern when applying sewage sludges to agricultural land are Pb, Zn, Cu, Ni and Cd. Several studies have been conducted to determine the range of metals in various municipal sewage sludges with representative data being presented in Table 2. Although both domestic wastes and urban run-off contain metals, it is felt that industrial wastes contribute the majority of metals found in municipal sewage sludges and that industrial pretreatment can significantly reduce the metal content of sludges (22). This view is also supported by the low metal content of sludges from treatment plants serving only residential areas. It has been suggested that a "typical" domestic sewage sludge would contain 2,500 mg Zn/kg, 1,000 mg Pb/kg, 1,000 mg Cu/kg, 200 mg Ni/kg and 25 mg Cd/kg, (23). However, since sludge-borne metals added to soils accumulate in the plant root zone (upper 20 cm), heavy metal loading is a consideration even when low metal sludges are applied to agricultural land.

The rationale for considering Pb, Zn, Cu, Ni and Cd involves protecting the human food-chain from metal contamination and preventing the deterioration of soil productivity. Lead additions to soils are limited

TABLE 2. CONCENTRATION OF SELECTED CONSTITUENTS IN SEWAGE SLUDGES.[a]

Component	Sommers (38)		Echelberger (12)[b]		Chaney (39)	
	Range	Median	Range	Median	Range	Median
	%					
N	<0.1 - 17.6	3.3	1.0 - 24.7	7.1	----	----
P	<0.1 - 14.3	2.3	----	----	----	----
K	<0.1 - 2.6	0.3	----	----	----	----
	mg/kg					
Pb	13 - 19,700	500	10 - 28,200	451	52 - 4,900	500
Zn	101 - 27,800	1,740	30 - 34,300	1,770	228 - 6,430	1,430
Cu	84 - 10,400	850	178 - 7,700	685	240 - 3,490	790
Ni	2 - 3,520	82	17 - 9,450	141	10 - 1,260	42
Cd	3 - 3,410	16	3 - 1,020	16	1 - 970	13

[a] All data on an oven-dry solids basis.

[b] PCB's: range, <0.04 - 241; median, 7.2.

Table 3. Effect of sewage sludge application on the concentration of Cd in selected crops.

Crop	Total Cd applied	Cd in vegetative tissue at a rel. sludge appl. rate of[a].				Cd in edible part at a relative sludge application rate of[a].				Ref.
		0	0.25	0.50	1.0	0	0.25	0.50	1.0	
	mg/kg									
Corn	101	0.2	1.4	3.2	10.9	0.09	0.18	0.40	0.81	28
	64	0.42	1.07	1.55	2.04	<0.05	<0.05	<0.05	<0.05	—[b]
	4.3	0.08	0.17	0.23	0.27	0.09	0.09	0.09	0.10	51
Soybeans	2.4	0.35	0.50	0.96	1.08	0.11	0.11	0.15	0.15	52
	77.6	0.22	0.89	2.73	5.78	0.31	0.31	0.57	0.92	45
	64	1.59	2.24	1.78	1.80	0.41	0.51	0.75	0.78	—[b]
Lettuce	3.3	----	----	----	----	0.61	1.28	1.72	2.67	53
	3.9	----	----	----	----	0.46	----	----	0.55	54
	5.5	----	----	----	----	0.46	----	----	1.70	54
Radishes	3.3	----	----	----	----	0.13	0.14	0.18	0.31	53
	3.9	0.92	----	----	0.88	0.29	----	----	0.33	54
	5.5	0.92	----	----	3.10	0.29	----	----	0.92	54
Tomato	3.3	----	----	----	----	0.08	0.20	0.33	0.33	53
	3.9	0.66	----	----	0.75	0.12	----	----	0.20	54
	5.5	0.66	----	----	2.10	0.12	----	----	0.39	54
Peas	3.3	0.02	0.13	0.16	0.20	<0.03	0.04	0.04	0.04	53
Beans	3.9	0.46	----	----	0.55	0.04	----	----	0.07	54
	5.5	0.46	----	----	1.70	0.04	----	----	0.23	54
Turnips	3.9	0.59	-----	----	0.59	0.42	----	----	0.42	54
	5.5	0.59	----	----	2.60	0.42	----	----	1.30	54
Oats	64	0.77	1.14	1.64	1.96	0.16	0.49	0.76	0.84	—[b]

[a] The amount of Cd applied for each treatment is equal to the relative rate times the total Cd applied.

[b] L. E. Sommers and D. W. Nelson, unpublished data.

because of the potential for direct ingestion of Pb contaminated soil or dust by animals or infants. It is well established that sludge applications do not result in appreciable increases in the Pb content of crops (23, 24). Even though Cu and Zn are essential micronutrients for all crops, excessive additions of Cu and Zn, along with Ni, can be toxic to plants resulting in undesirable depressions in crop yields. Fortunately, additions of sludge-borne Cu, Zn, and Ni to soils will not pose a health risk to animals or humans because the plant concentrations of these metals which cause phytotoxicity are lower than those causing health problems (24).

Cadmium has received the greatest attention as a potential human health problem resulting from application of sewage sludges on cropland. The concern over Cd arises from current estimates of dietary Cd intake by the U.S. population (26). After ingestion, Cd accumulates primarily in the kidney and, after extended exposure to elevated dietary Cd, a chronic kidney malfunction (proteinuria) may result (27). Thus, if sludge applications increase the Cd content in the human diet, there is the potential for a health problem after 20 to 50 years. In addition, excessive Cd levels can be obtained in plant tissues before phytoxicity occurs. It should be noted that only 1 to 2% of the agricultural cropland is required for application of all municipal sewage sludge produced in the U.S. (24).

Soil and plant factors influencing metal uptake by crops.

Since Cd is the metal of most concern, representative Cd data will be emphasized to illustrate the behavior of metals in soil-plant systems. Plant species differ markedly in their response to application of Cd contained in sewage sludges. The concentrations of Cd in several vegetable and crop species are shown in Table 3. In general, leafy vegetables tend to accumulate greater concentrations of Cd than fruit, tuber or grain crops. Also, the vegetative parts of most plants contain higher concentrations of Cd than the reproductive or storage organs. Even though the leaf can contain elevated Cd levels, only minimal increases in grain Cd are observed for corn (22, 24, 28-30), suggesting that corn is an ideal crop for soils treated with sludge. Other grain crops, such as soybeans, oats and wheat, also exclude Cd from entering the grain but to a lesser extent than corn (24). In addition to species differences in uptake of Cd from soils, cultivars of corn (31), soybeans (32), and lettuce (33) vary in Cd accumulation, indicating a potentital for plant breeding programs to develop cultivars which are ideally suited for growth on soils amended with sludge.

In general, the concentrations of Zn in crops tend to parallel those of Cd while Cu and Ni are altered to a smaller extent by sludge applications (24). As with Cd, Zn concentrations are greatest in the vegetative parts of plants rather than the fruit or grain.

Soil properties exert a strong influence on the uptake of metals by crops. The solubility of heavy metals in soils is likely controlled by sorption onto clay minerals or hydrous oxides of Fe, Al and Mn, chelation or complexation with organic matter and precipitation with phosphate, sulfide or carbonate anions (24). Either directly or indirectly, soil pH has a marked effect on the above metal retention mechanisms. Soil

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTION HERE

Table 4. Effect of soil pH on Cd concentration in representative crops.

Crop	Control soil[a]				Sludge-amended soil[a]			
	Soil pH		Tissue Cd		Soil pH		Tissue Cd	
	L	H	L	H	L	H	L	H
			----mg/kg----				----mg/kg----	
Lettuce (Bibb)	4.6	6.3	1.18	0.78	6.0	6.7	8.40	4.18
Lettuce (Romaine)	4.6	6.3	0.88	0.78	6.0	6.7	2.25	1.78
Lettuce (Boston)	4.6	6.3	0.95	0.90	6.0	6.7	3.10	1.85
Cabbage	4.6	6.3	0.19	0.16	6.0	6.7	0.35	0.19
Carrot	4.6	6.3	0.96	0.71	6.0	6.7	2.29	1.25
Swiss chard[c]	6.1	---	1.31	----	5.3	6.7	13.50	2.91
Corn grain	6.1	---	0.04	----	5.3	6.7	0.29	0.12
Swiss chard[d]	6.1	---	1.31	----	4.5	6.6	10.60	2.10
Corn grain	6.1	---	0.04	----	4.5	6.6	0.52	0.29
Lettuce[e]	4.9	6.3	1.6	0.6	4.9	6.3	20.4	4.6
Swiss chard	4.9	6.3	----	0.8	4.9	6.3	37.1	2.9
Soybean grain	4.9	6.3	0.20	0.08	4.9	6.3	1.07	0.38
Oat grain	4.9	6.3	0.22	0.04	4.9	6.3	2.12	0.38
Orchardgrass	4.9	6.3	0.34	0.17	4.9	6.3	1.67	0.66
Swiss chard[f]	5.7	6.7	0.6	0.5	5.2	6.2	1.9	0.6
Oat grain	5.7	6.7	0.05	0.04	5.2	6.2	0.23	0.07
Swiss chard[g]	5.3	6.4	0.89	0.49	5.6	6.6	70.4	17.7
Oat grain	5.3	6.4	0.11	0.07	5.6	6.6	3.38	0.54

[a] L = low pH; H = high pH

[b] pH adjusted by liming; 11.2 kg Cd/ha added in sludge [33].

[c] pH decreased (L) by adding S°; 80 metric tons/ha sludge applied [33].

[d] as in c but 240 metric tons/ha sludge applied.

[e] pH adjusted by liming; old sludge disposal site - total Cd in soil was 0.25 and 2.8 μg/g for control and sludge-treated soils, respectively [55].

[f] pH adjusted by liming; old sludge disposal site - DTPA extractable Cd was 0.13 and 0.55 μg/g for control and sludge-treated soils, respectively [22].

[g] as in f but DTPA extractable Cd was 0.94 and 6.3 μg/g for control and sludge-treated soils, respectively.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS

PAGE NUMBER
EPA-287 (Cin.) (4-76)

cation exchange capacity (CEC) is a function of soil clay and organic matter content and pH and has been used as an index of those soil properties minimizing metal solubility and thus plant uptake (34, 35). However, recent studies indicate that soil CEC per se is not likely to influence Cd concentrations in crops (36, 37).

Soil pH appears to be the critical parameter for minimizing uptake of sludgeborn metals by crops. The data presented in Table 4 illustrate the effect of soil pH on Cd uptake from sludge-amended soils by a variety of crops. In most cases, substantial reductions in plant Cd concentrations result from liming acid soils. Zinc concentrations in plants have been found to decrease from liming to a greater extent than Cd in some crops. It is also apparent that crops differ in Cd uptake following lime additions to increase soil pH. Metal uptake will be minimized by sludge applications to calcareous soil where the pH is continuously buffered by the presence of $CaCO_3$. In addition, the cation exchange sites in soil organic matter are weakly acidic functional groups which serve to buffer soil pH. Thus, CEC may be important in non-calcareous soils by minimizing pH changes during the oxidation of reduced N and S contained in sludges.

Limits for sludge metal additions to soils.

The U.S. EPA in addition to some state regulatory agencies have developed regulations concerning the maximum amounts of Pb, Zn, Cu, Ni and Cd allowable on agricultural land used for growing food-chain crops. Food-chain crops are typically defined as those crops than can enter the human diet either with (wheat, corn) or without (leafy vegetables) processing. Researchers in the USDA and Agricultural Experiment Stations proposed limits for Pb, Zn, Cu, Ni, and Cd which should allow the growth of all crops after termination of sludge applications, provided the soil pH is maintained at 6.5 or above (34). The metal loadings suggested are shown in Table 5. The use of soil CEC was based on the fact that metal solubility and thus, plant availability tends to decrease with increasing CEC in most soils of the north central United States. The CEC concept may be valid for Cu, Zn and Ni but it does not appear to be related to the plant availability of Cd (36, 37). Scaling metal additions to soil CEC does not imply that sludge-borne metals are present in soils as exchangeable cations because it has been well-established that nearly all metals in sludge-amended soils are nonexchangeable with a neutral salt (40, 41).

The U.S. EPA has developed regulations only for Cd additions to cropland (10). These limitations can be summarized as follows:

1. The pH of the soil/sludge mixture must be $\geq$ 6.5 at the time of sludge application.
2. Annual Cd additions are limited to 0.5 kg/ha/yr if leafy vegetables, root crops, vegetables or tobacco are grown.

EPA-287 (Cin.)
(4-76)

Table 5. Maximum amounts of Pb, Zn CU, Ni, and Cd that can be applied to agricultural cropland (34, 35).

Metal[a]	Soil cation exchange capacity, meq/100 g <5	5-15	>15
	kg/ha		
Pb	500	1,000	2,000
Zn	250	500	1,000
Cu	125	250	500
Ni	125	250	500
Cd[b]	5	10	20

[a] Soil must be maintained at pH 6.5 or above.

[b] Contained in U.S. EPA Criteria (10).

3. For other food-chain crops, the annual Cd additions follow a phased reduction from 2 kg/ha/yr (present to 6/30/84), to 1.25 kg/ha/yr (7/1/84 to 12/31/86), to 0.5 kg/ha/yr (after 1/1/87).

4. The cumulative Cd applied must be < 5 kg/ha if the background soil pH is ≤ 6.5.

5. The cumulative Cd applied is as shown in Table 5 for soils with a background pH≥ 6.5 and for soils with a background pH ≤ 6.5 provided the pH is 6.5 at the time food-chain crops are grown.

For soils used for growth of animal feed only, neither annual nor cumulative Cd application limits were established but soil pH must be 6.5 and a detailed facility plan is needed to prove that the crop will not directly enter the human diet. Only guidelines have been established for Pb, Zn, Cu and Ni by the U.S. EPA (35).

Nitrogen

The factor limiting the annual application rate of many sludges is the available N content. A potential problem in land application of sludges is the leaching of NO_3^- below the plant root zone and ultimately into ground water. This can occur when available N additions to soils exceed the N requirement of the crop grown whether the N added is from sludge, animal manures, or fertilizers. Thus, a well-designed system will use annual sludge application rates which are consistent with the N needs of the crop grown.

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

Table 6. Effect of annual sewage sludge applications on yields of corn and soybeans.

Crop	Year	Max. annual sludge applied	Grain yield at a relative sludge application rate of[a]			
			0[b]	0.25	0.5	1.0
		metric tons/ha				
Soybeans (ref. 45)	1969	43	2.28	3.02	3.24	3.36
	1970	59	2.01	2.77	3.02	2.85
	1971	109	1.80	1.93	2.10	2.13
	1972	31	2.04	2.55	2.74	2.93
	1973	14	1.68	1.90	2.00	2.11
	1974	59	1.44	1.71	2.00	2.12
Corn (ref. 28)	1968	51	4.16	6.03	7.16	7.02
	1969	48	8.96	9.34	9.42	9.44
	1970	53	5.53	7.48	7.62	8.63
	1971	128	6.06	6.50	6.92	7.88
	1972	26	8.94	8.62	8.99	8.82
	1973	62	4.00	6.05	6.72	7.63
	1974	49	3.47	3.21	3.85	5.11
	1975	---	8.15	9.36	9.44	9.43

[a] Sludge application rates can be calculated by multiplying 0, 0.25, 0.5, or 1.0 and the maximum rate shown.

[b] Control plots were fertilized with K for soybeans and with N, P and K for corn.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

Table 7. Effect of sludge type on corn grain yields (47).

Soil type	Year	Grain yield[a]				
		No N	NH_4NO_3	Ca-sludge	Al-sludge	Fe-sludge
		metric tons/ha				
Conestoga loam	1973	4.17	5.97	5.94	5.39	5,81
	1974	4.89	6.57	6.47	7.11	7.03
	1975	7.13	7.67	7.00	8.03	7.61
Caledon loamy sand	1973	3.88	3.43	3.47	3.05	3.03
	1974	3.87	4.21	3,87	3.78	4.52
	1975	3.63	3.75	4.46	3.00	3.53
Oneida clay loam	1973	3.71	3.55	5.12	3.55	4.56
	1974	1.58	1.44	3.35	1.61	2.32
	1975	5.56	4.70	6.04	5.78	5.86

[a] Nitrogen application rates were 100 kg N/ha from NH_4NO_3 and 200 kg N/ha from Ca-, Al- or Fe-sludge. Anaerobically digested sludges from three treatment plants where either $Ca(OH)_2$, $Al_2(SO_4)_2$ or $Fe\ Cl_3$ was added for P removal during waste water treatment.

EPA-287 (Cin.)
(4-76)

Several fractions of N in sewage sludge are available for plant uptake. In anaerobically digested sludges, NH_4^+ constitutes from 25 to 50% of the total N while NO_3^- is present in only trace amounts (42). Both NH_4^+ and NO_3^- are readily available for plant uptake. The organic N applied to soils in sewage sludge will undergo partial decomposition resulting in release of plant available inorganic N. The amount of organic N mineralization is usually estimated from laboratory or field decomposition studies which suggest that from 15% (43) to 20% (34) of the organic N is released the first year after application. In subsequent years, the percentage of organic N mineralized decreases.

Part of the N applied to soils in sewage sludge will be lost through volatilization on denitrification. Following surface application of sludges, up to 60% of the NH_4^+-N can be lost through NH_3 volatilization (44). Thus, the rate of sludge applied each year to provide adequate N for plant growth is greater for surface than incorporated applications (34, 35). Nitrate losses can also occur after sludge application through denitrification (microbial reduction of NO_3^- to N_2O and N_2 under anaerobic conditions). This N loss is not corrected for directly but it has been considered in the development of conventional N fertilizer recommendations for various crops. Nitrogen fertilizer recommendations have been developed in all regions of the U.S. for the major crops grown and these values are used in determining the appropriate sewage sludge application rate for cropland.

Several field experiments have been conducted to compare yields of crops grown on soils fertilized with sewage sludge and conventional inorganic fertilizer materials. Representative data for crop yields are shown in Tables 6 to 8. In essence, crop yields are increased with increasing rates of sludge application. The data in Table 6 are also noteworthy in that the recommended metal limits shown in Table 5 were exceeded for Cd and Zn without a reduction in yield (soil pH $\geq$ 6.5). Elemental analysis of the leaf and grain of corn (28) and soybeans (45) indicated that both Zn and Cd were elevated by sludge application.

Corn grain yields have been determined on soils treated annually with NH_4NO_3 and three different anaerobically digested sludges (47). Sludges applied at a rate of 200 kg N/ha gave similar corn grain yeilds as 100 kg N/ha added as NH_4NO_3 (Table 7). On the loamy sand soil, no yield response was obtained for either NH_4NO_3 or sludge. The yeild response of corn was similar for all three types of sludges. Soil analysis indicated that NO_3^--N concentrations in the 0-15 cm depth averaged 92 and 59 mg/kg for soils treated with 400 kg N/ha as NH_4NO_3 and sludge, respectively. This study concluded that the optimum rate of sludge application was 200 kg N/ha for corn resulting in minimal leaching of NO_3^- into ground water. In a related study, it was shown that yields of both rye forage and corn grain increased with increasing sludge application rates (Table 8). Corn grain yields were significantly increased for three years following a single application of sludge. This result is consistent with mineralization of organic N for several years after sludge is applied to soils. The studies cited along with others indicate that optimum yields of agronomic crops can be obtained with an appropriate rate of sludge application.

DESIGN CRITERIA FOR LAND APPLICATION SYSTEMS

As discussed in the previous sections, the major considerations in use of sewage sludge on agricultural land are: (1) pathogens; (2) persistent organics; (3) heavy metals - Pb, Zn, Cu, Ni and Cd and; (4) available N. In addition, sludge applications should not result in contamination of surface waters as a result of runoff. This potential problem can be alleviated by incorporating the sludge into the soil, surface-applying sludge on only relatively level soils (i.e., <6% slope), and minimizing sludge application on frozen soils. Additional information on other site selection considerations has been discussed in recent reviews (34, 48, 49).

Table 8. YIELD OF RYE FORAGE AND CORN GRAIN FOLLOWING A SINGLE APPLICATION OF SEWAGE SLUDGE TO A PLANO SILT LOAM SOIL (46)

Sludge applied	Year[a] 1	2	3	4
	metric tons/ha			
0	3.75	3.14	2.00	1.35
3.75	3.91	3.84	2.13	1.07
7.5	4.00	4.82	2.93	1.35
15	4.06	5.68	3.55	3.14
30	4.02	6.38	5.34	3.14
60	3.77	7.13	5.91	4.78

[a] Corn grain yields except for rye forage in year 1.

To design a system for land application of sewage sludge, information is required on the (1) composition of sewage sludge; (2) soil properties (pH and CEC) and fertility status and; (3) type and yield level of crop to be grown. Based on this data, sludge application rates and supplemental fertilizer needs are determined for each year and the total amount of sludge that can be applied over a period of years is based on cumulative additions of Pb, Zn, Cu, Ni or Cd. This basic approach has been recently discussed (50) and can be summarized as follows:

1. Obtain fertilizer (N, P and K) recommendation for crop grown.
2. If first sludge application proceed to step 3
   a. Correct fertilizer recommendation for amounts of residual N, P and K from previous sludge applications.
3. Select minimum sludge application rate from:
   a. N limitation - sludge-borne plant available N (NH_4^+ + NO_3^- + 20% of organic N) applied should equal corrected N fertilizer recommendation.
   b. Cd limitation - as specified in the U.S. EPA Criteria (10).

4. At the rate selected in step 3, calculate the amounts of P and K needed to optimize crop yield.
5. Sum the Pb, Zn, Cu, Ni and Cd added each year.
6. If a metal limit has been exceeded (Table 5) terminate sludge applications; otherwise, proceed to step 1.

This approach assumes that soil pH is maintained at 6.5 or above whenever sludge is applied. Since the annual application rates are consistent with current fertilizer practices, monitoring in excess of routine soil testing for available P and K and pH is not required. It must be realized that the above steps only apply to sludges that have been stabilized by an appropriate process and that persistent organics (i.e., PCB's) are not present at concentrations <10 mg/kg.

In summary, sewage sludge can be readily used in the production of agronomic crops to obtain yields comparable to those from using conventional fertilizer materials. However, additional management is required to assure that allowable amounts of Cd and organics are applied to soils, that soil pH is maintained at 6.5 or above, that sludge applications cease before phytotoxic concentrations of metal accumulate in soils and that the appropriate crops are grown.

ACKNOWLEDGMENT

Research supported, in part, by Western Regional Project W-124 entitled "Optimum Utilization of Sewage Sludge on Agricultural Land", and published with the approval of the Director of the Agricultural Experiment Station, Purdue University, as Journal Paper No. 8105.

LITERATURE CITED

1. Burge, W. D., and P. B. Marsh. 1978. Infectious disease hazards of land spreading sewage wastes. J. Environ. Qual. 7:1-9.

2. Wellings, F. M., A. L. Lewis, and C. W. Mountain. 1974. Virus survival following wastewater spray irrigation of sandy soil. pp. 253-260. *In* J. F. Malina, Jr., and B. P. Sagik (Ed.), Virus Survival in Water and Wastewater Systems. Center for Research in Water Resources, Univ. of Texas, Austin, TX.

3. Sagik, B. P., and C. E. Sorber. 1978. Risk Assessment and Health Effects of Land Application of Municipal Wastewater and Sludges. Center for Applied Research and Technology, Univ. of Texas at San Antonio, San Antonio, TX.

4. Gerba, C. P., C. Wallis, and J. L. Melnick. 1975. Fate of wastewater bacteria and viruses in soil. J. Irrigation and Drainage Division, Amer. Soc. Civil Engineering IR 3:157-174.

5. Zibilske, L. M., and R. W. Weaver. 1978. Effect of environmental factors on survival of *Salmonella typhimurium* in soil. J. Environ.

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

Qual. 4:593-597.

6. Well, R. G., and J. B. Bole. 1978. Elimination of fecal coliform bacteria from soil irrigated with a municipal sewage lagoon affluent. J. Environ. Qual. 7:193-196.

7. Bell, R. G. 1976. Persistence of fecal coliform indicator bacteria on alfalfa irrigated with municipal sewage lagoon affluent. J. Environ. Qual. 5:39-42.

8. Zenz, D. R., J. R. Peterson, D. L. Brooman, and C. Lue-Hing. 1976. Environmental impacts of land application of sludge. J. Water Pollution Control Fed. 48:2332-2342.

9. Elliott, L. F., and J. R. Ellis. 1977. Bacterial and viral pathogens associated with land application of organic wastes. J. Environ. Qual. 6:245-251.

10. Criteria for Classification of Solid Waste Disposal Facilities and Practices: Final, Interim Final, and Proposed Regulations (as corrected in the Federal Register of September 21, 1979). 1979. Federal Register 44:53438-53469.

11. Furr, A. K., A. W. Lawrence, S. S. C. Tong, M. C. Grandolfa, R. A. Hofstader, C. A. Bache, W. H. Lawrence and D. J. Lisk. 1976. Multi-clement and chlorinated hydrocarbon analysis of municipal sewage sludges of American cities. Environ. Sci. Technol. 10:683-687.

12. Echelberger, W. F., Jr., J. M. Jeter, F. P. Girardi, P. M. Ramey, G. Glen, D. Skole, E. Rogers, J. C. Randolph, and J. Zogorski. 1979. Municipal and industrial wastewater sludge inventory in Indiana: Chemical characterization of municipal wastewater sludge in Indiana, Part 1. School of Public and Environmental Affairs, Indiana University, Bloomington, IN 47401.

13. R. Sprague, Michigan Department of Natural Resources, Personal Communication.

14. Helling, C. S., P. C. Kearney, and M. Alexander. 1971. Behavior of pesticides in soils. Advan. Agronomy 23:147-240.

15. Iwata, Y., W. E. Westlake, and F. A. Gunther. 1973. Varying persistence of polychlorinated biphenyls in six California soils under laboratory conditions. Bulletin Environ. Contamin. Toxicol. 9:204-211.

16. Clark, R. R., E. S. K. Chian, and R. A. Griffin. 1979. Degradation of polycholorinated biphenyls by mixed microbial cultures. Applied Environ. Microbiol. 37:680-685.

17. Iwata, Y., F. A. Gunther, and W. E. Westlake. 1974. Uptake of a PCB (Aroclor 1254) from soil by carrots under field conditions. Bulletins Environ. Contamin. Toxicol. 11:523-528.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

18. Jacobs, L. W., S. F. Chou, and J. M. Tiedje. 1976. Fate of PBB's in soils: Persistence and plant uptake. J. Agric. and Food Chem. 24:1198-1201.

19. Haque, R., D. W. Schmedding, and V. H. Freed. 1974. Aqueous solubility, adsorption, and vapor behavior of polychlorinated biphenyl Aroclor 1254. Environ. Sci. Technol. 8:139-142.

20. Chaney, R. L., and C. A. Lloyd. 1979. Adherence of spray-applied liquid digested sewage sludge to tall fescue. J. Environ. Qual. 8:407-411.

21. Fries, G. F. 1980. An assessment of potential residues in animal products from application of sewage sludge containing polychlorinated biphenyls to agricultural land. Presented at Symposium on Evaluation of Health Risks Associated with Animal Feeding and/or Land Application of Municipal Sludge, Tampa, FL.

22. Chaney, R. L., and S. B. Hornick. 1978. Accumulation and effects of cadimum on crops. Proc. First International Cadimum Conference. pp. 125-140.

23. Chaney, R. L., and P. M. Giordano. 1977. Microelements as related to plant deficiencies and toxicities. In L. F. Elliott and F. G. Stevenson (eds.), Soils for Management of Organic Wastes and Wastewaters, Soil Science Society of America, Madison, WI. pp. 235-279.

24. Application of sewage sludge to cropland: Appraisial of potential hazards of the heavy metals to plants and animals. Rpt. No. 64, Council for Agricultural Science and Technology, Ames, IA. (Also reprinted as MCD-33 (EPA-430/9-76-013) by the U.S. Environmental Protection Agency).

25. Chaney, R. L. 1973. Crop and food chain effects of trace elements in sludges and effluents. Proc. of Conference on Recycling Municipal Sludges and Effluents on Land, National Association of State Universities and Land Grant Colleges, Washington, D. C. pp. 129-141.

26. Braude, G. L., C. F. Gelinek, and B. Corneliussen. 1975. FDA's overview of the potential health hazard associated with the land application of municipal wastewater sludge. In Proc. 1975 National Conference Municipal Sludge Management and Disposal. Information Transfer, Inc., Rockville, M.D., pp. 214-217.

27. Doyle, J. J. 1977. Effects of low levels of dietary cadimum in animals--a review. J. Environ. Qual. 6:111-116.

28. Hinesly, T. D., R. L. Jones, E. L. Ziegler, and J. J. Tyler. 1977. Effects of annual and accumulative applications of sewage sludge on the assimilation of zinc and cadimum by corn (*Zea mays* L.). Environ. Sci. Technol. 11:182-188.

EPA-287 (Cin.)
(4-76)

29. Hinesly, T. D., E. L. Ziegler, and G. L. Barrett. 1979. Residual effects of irrigating corn with digested sewage sludge. J. Environ. Qual. 8:35-38.

30. Webber, L. R., and E. G. Beauchamp. 1979. Cadimum concentration and distribution in corn (Zea mays L.) grown on a calcareous soil for three years after three annual sludge applications. J. Environ. Sci. and Health B-14:459-474.

31. Hinesly, T. D., D. E. Alexander, E. L. Ziegler, and G. L. Barrett. 1978. Zinc and cadimum accumulation by corn inbreds grown on sludge amended soil. Agron. J. 70:425-428.

32. Boggess, S. F., S. Willavize, and D. E. Koeppe. 1978. Differential response of soybean varieties to soil cadimum. Agron. J. 70:756-760.

33. Giordano, P. M., D. A. Mays, and A. D. Behel, Jr. 1979. Soil temperature effects on uptake of cadimum and zinc by vegetables grown on sludge-amended soil. J. Environ. Qual. 8:233-236.

34. Application of Sludges and Wastewaters on Agricultural Land: A Planning and Educational Guide. 1976. B. D. Knezek and R. H. Miller (eds.), North Central Regional Research Publication 235, Ohio Agricultural Research and Development Center, Wooster, OH. (Also reprinted by the U. S. Environmental Protection Agency as MCD-35).

35. Municipal Sludge Management: Environmental Factors. 1977. MCD-28 (EPA430/9-77-007) U.S. Environmental Protection Agency, Washington, D. C.

36. Latterell, J. J., R. H. Dowdy, and G. E. Ham. 1976. Sludge-borne metal uptake by soybeans as a function of soil cation exchange capacity. Commun. Soil Sci. and Plant Analysis 7:465-476.

37. Haghiri, F. 1974. Plant uptake of cadimum as influenced by cation exchange capacity, organic matter, zinc and soil temperature. J. Environ. Qual. 3:180-183.

38. Sommers, L. E. 1977. Chemical composition of sewage sludges and analysis of their potential use as fertilizers. J. Environ. Qual. 6:225-232.

39. Chaney, R. L., S. B. Hornick, and P. W. Simon. 1977. Heavy metal relationships during land utilization of sewage sludge in the northeast. In R. C. Loehr (ed.), Land as a Waste Management Alternative. Ann Arbor Science, Ann Arbor, MI. pp. 283-314.

40. Silviera, D. J., and L. E. Sommers. 1977. Extractability of copper, zinc, cadimum, and lead in soils incubated with sewage sludge. J. Environ. Qual. 6:47-52.

EPA-287 (Cin.)
(4-76)

41. Latterell, J. J., R. H. Dowdy, and W. E. Larson. 1978. Correlation of extractable metals and metal uptake of snapbeans grown on soil amended with sewage sludge. J. Environ. Qual. 7:435-440.

42. Sommers, L. E., D. W. Nelson, and K. J. Yost. 1976. Variable nature of chemical composition of sewage sludges. J. Environ. Qual. 5:303-306.

43. Keeney, D. R., K. W. Lee, and L. M. Walsh. 1975. Guidelines for the Application of Wastewater Sludge to Agricultural Land in Wisconsin. Technical Bulletin No. 88, Dept. of Natural Resources, Madison, WI.

44. Beauchamp, E. G., G. E. Kidd, and C. Thurtell. 1978. Ammonia volatilization from sewage sludge applied to the field. J. Environ. Qual. 7:141-146.

45. Hinesly, T. D., R. L. Jones, J. J. Tyler, and E. L. Ziegler. 1976. Soybean yeild responses and assimilation of Zn and Cd from sewage sludge-amended soil. J. Water Pollution Control Fed. 48:2137-2152.

46. Kelling, K. A., A. E. Peterson, L. M. Walsh, J. A. Ryan, and D. R. Keeney. 1977. A field study of the agricultural use of sewage sludge: I. Effect on crop yield and uptake of N and P. J. Environ. Qual. 6:339-344.

47. Soon, Y. K., T. E. Bates, E. G. Beauchamp, and J. R. Moyer. 1978. Land application of chemically treated sewage sludge: I. Effects on crop yield and nitrogen availability. J. Environ. Qual. 7:264-269.

48. Witty, J. E., and K. W. Flach. 1977. Site selection as related to utilization and disposal of organic wastes. In L. F. Elliott and F.J. Stevenson (eds.), Soils for Management of Organic Wastes and Wastewaters, Soil Science Society of America, Madison, WI. pp. 327-345.

49. Principals and design criteria for sewage sludge application on land. 1978. In Sludge Treatment and Disposal, Part II, Sludge Disposal. Environmental Research Information Center, U. S. Environmental Protection Agency (EPA-625/4-78-012). pp. 57-112.

50. Sommers, L. E., and D. W. Nelson. 1978. A model for application of sewage sludge on cropland. In Proc. First Annual Conference of Applied Research and Practice on Municipal and Industrial Wastes, Madison, WI. pp. 307-326.

51. Kelling, K. A., D. R. Keeney, L. M. Walsh, and J. A. Ryan. 1977. A field study of the agricultural use of sewage sludge: III. Effect on uptake and extractability of sludge-borne metals. J. Environ. Qual. 6:353-358.

52. Ham, G. E., and R. H. Dowdy. 1978. Soybean growth and composition as influenced by soil amendments of sewage sludge and heavy metals: Field studies. Agron. J. 70:326-330.

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

53. Dowdy, R. H., and W. E. Larson. 1975. The availability of sludge-borne metals to various vegetable crops. J. Environ. Qual. 4:278-282.

54. Giordano, P. M., and D. A. Mays. 1977. Yield and heavy-metal content of several vegetable species grown on soil-amended with sewage sludge. In H. Drucker and R. E. Wildung (eds.), Biological Implications of Metals in the Environment. National Technical Information Services, Springfield, VA (Conf-750929). pp. 417-425.

55. Chaney, R. L., P. T. Hundemann, W. T. Palmer, R. J. Small, M. C. White, and A. M. Decker. 1978. Plant accumulation of heavy metals and phytotoxicity resulting from utilization of sewage sludge and sludge composts on cropland. In Proc. Conf. on Composting of Municipal Residues and Sludges, Information Transfer, Inc. Rockville, MD. pp. 86-97.

6-1/2"
9-1/8"
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

PB83-142299

UTILIZATION OF ACTIVATED SLUDGE FROM COMBINED MUNICIPAL/INDUSTRIAL WASTEWATER TREATMENT FOR ANIMAL AND POULTRY FEED

MATMOR Central Feed Mill
Mobil Post Evtach, Israel

TEXT

I work at the largest feed mill in Israel which produces 22-24,000 m. tons per month of finished feed for farm livestock. As nutritionists, we have to look for unconventional materials for feed. Almost all of our raw materials for livestock feed comes from the U.S.A., the prices of which are frequently increasing.

We are now taking into account new materials such as dried poultry manure for ruminants and activated sludge from sewage for monogastric animals.

The approach of the nutritionist to sludge is from a nutritional point of view only. Upon approaching such a product, the following should be checked.

1) If the material is free from harmful elements, bacteria, pesticides, herbicides, etc.
2) That the material has a nutritional value, and will be economical, at least regarding protein and energy.

The first material I would like to talk about is DIGOSOL (which is registered in Israel), which is the end product of a methane fermentation system. It is used mainly as a feed component for cattle and pigs, and can also be safely used for daily cattle but with little advantage.

TABLE 1 CHEMICAL ANALYSIS

Crude Protein (N x 6.25)	13% ± 2
Crude Fat	4% ± 1
Cellulose	9% ± 1
Nitrogen-free Extract	18% ± 1
Total Organic Matter	44% ± 3
Ash	52% ± 3
Moisture	10% ± 1

TABLE 2 COMPOSITION OF ASH:

Calcium	11 - 14%
Phosphorus	1.8 - 2.2%
Iron	1.0 - 1.2%
Magnesium	0.8 - 1.2%
Cobalt	200 ppm
Copper	300 ppm
Manganese	350 ppm
Zinc	2500 ppm

TABLE 3 COMPOSITION:

		Digosol	Cottonmeal	Soyameal
Crude Protein	kg	135	415	440
Crude Fat	kg	45	15	10
Crude Fiber	kg	90	125	70
Calcium	kg	120	1.5	2.5
Phosphorus	kg	20	9.8	6.0
T.D.N. (Total Digestible Nutrient)		475	725	760

A trial was conducted to establish the influence of Digosol on the rate of growth and feed conversion of calves. The experimental group was fed the same diet from which was removed the following:

10 kg corn
2 kg D.C.P.
5 kg soyameal
8 kg limestone

and was replaced by 25 kg. Digosol.

Twelve calves (Frezian, an Israeli breed) took part in the trial. Each animal was weighed at the beginning and end of the trial and at regular monthly intervals. The animals were fed ad lib. In addition to the above-mentioned feed, each calf received 2 kg. of hay daily.

TABLE 4 RESULTS:

	Digosol	Control
No. of calves	6	5
Average starting weight	274.2 kg	271.0 kg
Average weight at completion	478.0 kg	473.0 kg
Average general addition of weight	203.8 kg	202.8 kg
No. of days of trial	183 days	191 days
Average daily weight increase (gm)	1114 ± 30 gm	1062 ± 29 gm

The Digosol group of calves increased their weight during 183 days by only 1 kg. Therefore, we can assume that feed containing 25 kg. Digosol is in no way harmful and no change was found in the calves.

The second product I would like to talk about is activated sludge. According to the experts, from 1 cu. m. of sewage we can produce ½ kg. of sludge.

The first study is a trial of baby chicks who were fed dried sludge. The results of this trial showed us that chicks can be fed such sludge without suffering harmful consequences. There was no mortality and no lack of appetite. The sludge was sterilized at the nuclear center at Nahal Soreq.

TABLE A CHEMICAL ANALYSIS:

Crude Protein	30.7%
N.P.N. (Non-protein nitrogen)	5.2%
Crude Fat	2.2%
Ash	29.7%
Absorbed Protein	57.2%
Metabolic Energy	2315

TABLE B AMINO ACIDS

	A.S.	Cottonmeal	Soyameal
Argimine	6.15	11.0	7.48
Lysine	4.17	4.13	6.30
Methionine	2.12	1.25	1.44
Cystine	0.37	1.54	1.49
Histidine	1.56	2.65	2.37
Leucine	8.31	5.82	7.48
Isoleucine	4.69	3.21	5.28
Phenybalamine	5.41	5.36	4.95
Tytosine	4.17	2.46	3.08
Valine	6.97	4.56	4.98

Trial of chicks

The trial was carried out with baby chicks one week old, and for the first week they received standard feed.

TABLE C

	kg	kg	kg
Activated sludge	0	50	100
Soya	320	270	230
Ground nut hulls	0	20	15
Sorghum	420	420	420
Corn	150	150	150
Oil	40	40	40
Alfalfa	20	20	20
Fish meal	20	20	20
D.C.P.	14	0	0
Limestone	9	0	0
Salt	2.5	0	0
Methionine	1.4	1.5	1.6
Vitamin	3.5	3.5	3.5
Crude protein	21.2	21.2	21.2
Protein tested	23.4	22.3	19.1
Metabolic energy	2680	2840	2830

TABLE D RESULTS:

Activated sludge	0 kg	50 kg	100 kg
2 - 3 weeks			
Weight increase - gm.	227	215	213
Feed consumption	370	363	379
Feed efficiency	1.63	1.69	1.78
3 - 4 weeks			
Weight increase - gm.	296	286	281
Feed consumption	537	515	527
Feed efficiency	1.81	1.95	1.85
1 - 4 weeks			
Weight increase - gm.	665	640	636
Feed consumption	1113	1085	1127
Feed efficiency	1.67	1.70	1.77

The increase in weight was almost equal in the trials. Whatever the chemical analysis a low amount of protein was found which is the reason for the slight difference in weight.

I would like to point out that in previous studies a big liver was found. In the group that was fed 100 kg. sludge, the big liver is a sign that the sludge contains some toxic elements.

Both these materials contain a large amount of Ash, which does not have to be considered as a negative aspect where added nutrients can be utilized.

The biggest problem we have here is the lack of uniformity, which stems from the difference between the basic materials.

PB83-142307

WATER POLLUTION: INDUSTRY AND GOVERNMENT WORKING TOGETHER - A CASE STUDY OF MUNCIE, INDIANA'S INDUSTRIAL PRETREATMENT PROGRAM.

J. M. Craddock
Director
Division of Water Quality
Muncie, Indiana 47304

This is a technical conference dealing with the many and varied problems involving industrial waste entering municipal plants. There have been and will be many papers presented on the technical side of industrial problems, therefore I would like to also address some closely related areas.

I believe when one looks at a case study of this type one must also look at and address areas other than just parts per million (ppm) or percent reduction. In order to have a reduction of industrial waste such as heavy metals there were certain attitudes, philosophies and modes of operation that were used or instituted to achieve this goal.

The question needs to be asked, what can a community do to have direction over its own future in the area of water pollution control, and the proper operation of its wastewater treatment plant with regard to industrial waste, the setting of industrial waste limits and protecting its receiving stream.

With the passing of Public Law 92500 in 1972, plus other new laws and regulations being instituted on the state and federal level, the ability for local Government and industry to keep up with the new and changing requirements in the field of industrial control is becoming almost impossible. In March 1972, the city of Muncie, Indiana created the Division of Water Quality,a testing and enforcement agency within the Muncie Sanitary District.

Muncie, Indiana, is a typical midwestern community having a population of approximately 100,000. Located north of Indianapolis, Muncie has a significant industrial sector employing over 30 percent of the local work force. The White River flows through the city, ultimately receiving the storm runoff, as well as the effluent from the wastewater treatment plant.

With the addition of the DWQ, the MSD program became a "total" approach because now the MSD had the additional flexibility to monitor water quality, establish standards, control industrial dischargers and enforce pretreatment regulations. Protection of the Muncie water resources could now be performed by a local agency responsible to the citizens of Muncie. This approach is similar to fire or police protection at the local level. Protection of the water resources in Muncie should be the responsibility of Muncie residents. Only when the local agency fails to provide this service should state or Federal agencies step in.

The initial responsibilities of the DWQ were as follows:

(a) Perform all laboratory testing for the wastewater treatment plant;

(b) Monitor the industrial dischargers using the MSD sewerage system and wastewater treatment plant;

(c) Enforce the applicable MSD ordinances relating to sewer use and pretreatment and develop new ordinances if necessary;

(d) Prepare spill control and countermeasure capabilities to minimize water pollution and/or fish kills in the event of a spill;

(e) Assume responsibility for testing local swimming areas for bacterial safety;

(f) Perform any scientific research in the aspects of water pollution necessary for the MSD to fully meet its responsibilities to the Muncie area citizens; and

(g) Monitor all streams and locate illegal discharges.

In 1972, the need for a formal industrial pretreatment program in Muncie was based on the recognition of five factors. These were:

(a) A significant industrial sector existed in Muncie discharging an unknown quantity of wastewater of an unknown quality into the MSD system.

(b) Existing heavy metals data for plant influent and sludge suggested relatively high metals concentrations;

(c) Industrial wastes are not always compatible with domestic sanitary wastewater treatment plants;

(d) A method was needed to assure that all non-domestic users of the MSD system were assessed fees in a fair and equitable manner; and

(e) The receiving stream for MSD effluent was particularly sensitive due to low flow conditions and no dilution during the summer.

In recognition of these factors, we initiated a program to develop a new, more detailed sewer use ordinance and develop a data base upon which to support the ordinance and the regulation of non-domestic dischargers to the MSD system.

The overall objectives of the industrial pretreatment program were as follows:

(a) Minimize potential upset conditions at the treatment plant due to industrial discharges;

(b) Minimize incompatible pollutants from passing through the treatment plant to the White River;

(c) Minimize treatment plant sludge disposal problems caused by excessive concentrations of toxic materials;

(d) Establish and maintain a data base sufficient to calculate sewer use surcharge fees;

(e) Prevent water quality violations resulting from illegal direct dischargers into surface waters within the MSD jurisdictional boundaries.

A good data base was essential to the pretreatment program including process descriptions, plant layout, personnel, water usage, and a complete effluent quality profile. The more accurate this information, the more fairly the pretreatment program can be implemented. An accurate data base which is continually updated is critical to the long term viability of the program. This is due to the fact that decisions regarding surcharge fees and enforcement of discharge standards must be based on accurate information. If not, the credibility of the program suffers. This leads to lack of community cooperation and program failure.

There are various approaches to develop an acceptable data base. With respect to effluent quantity and quality, the DWQ chose to sample and analyze the samples in our own laboratory. This approach was selected because we believed it would provide the most reliable and consistent results. Obviously, this approach is more costly and time consuming for the DWQ than, for example, requiring each user to furnish such data.

Shortly after the DWQ was established, we began the first step in the process of developing an industrial user data base. Files were developed for each known or suspected industrial discharger to the MSD system. Information was obtained from existing files of the wastewater treatment plant, industrial directories of the Chamber of Commerce, and water department billing records. Every possible discharger was included.

The next step was to visit each industry, beginning with the known users of the MSD system. The purpose of the on-site inspection program was two-fold. First, to visit each potential discharger to determine if the physical plant, storage practices and operations might result in accidental spills of toxic or otherwise unwanted materials to the sewer system. Often, manufacturing facilities, even though they may not normally produce a wastewater discharge, utilize materials which could enter the sewerage system. Secondly, known dischargers were visited to go through the manufacturing process with appropriate plant personnel to identify water uses and probable contaminants in the discharge. This information was used to decide the nature of the monitoring and subsequent analysis program.

Upon completion of the plant visits, all information collected was reviewed to determine the appropriate order in which the plants would be sampled. The plants discharging industrial wastes were scheduled for sampling ahead of those discharging domestic wastes. They were ranked to determine the priority of the field sampling program. Ranking was based upon the following criteria:

(a) Type of waste constituents - toxics receiving higher priority;

(b) Flow volume;

(c) Access to sampling points; and

(d) Whether existing data were available.

After several years of testing the Division established the following limits for metals:

LIMITATIONS ON WASTEWATER STRENGTH

Pollutant	Daily Average (mg/l)
Total Cadmium	0.2
Total Copper	2.0
Total Lead	2.0
Total Nickel	2.0
Total Chromium	2.0
Total Zinc	4.0
Total Cyanide	2.0

The establishment of these limitations at Muncie was based upon several years of monitoring not only the industrial contributors, but also the plant's influent, effluent, sludge, and water quality above and below the treatment plant. Developing specific limitations first requires a knowledge of the industrial processes, the metals loading to the plant from industry, the actual removal capabilities of the wastewater treatment plant, sludge disposal requirements and stream water quality.

The DWQ may require the user to construct monitoring facilities to allow DWQ personnel access for sampling flow measurement. Agency personnel may also inspect the facilities of any user at any reasonable time. Facilities include all manufacturing areas. Plans and specifications for pretreatment facilities proposed by users must be submitted to the DWQ before construction begins. The DWQ must be notified 48 hours prior to startup of new or modified pretreatment facilities. Spill containment facilities, when appropriate, must be provided by each user. Specific plans for such facilities must be submitted and approved by the DWQ. When a spill to the sewerage system does occur, the user must notify the DWQ immediately.

Effective implementation of the industrial waste control program requires the continuous collection of data defining the characteristics of the industrial users of the MSD system.

Data obtained from the industrial monitoring program are used for the following purposes:

(a) To determine compliance with the pretreatment standards contained in the Industrial Waste Control ordinance;

(b) To determine the appropriate user surcharge fees;

(c) To support appropriate enforcement action when necessary;

(d) To complete reports and forms for the DWQ and state/Federal agencies; and

(e) To provide a data base to justify modifications to the existing ordinance when appropriate.

The DWQ presently monitors approximately thirty industrial dischargers on a routine, unscheduled basis. Eight of these are monitored for determining surcharges. Other types of monitoring are performed as necessary. These include scheduled and demand monitoring. Scheduled monitoring means that the DWQ staff notifies the discharger on the day the sampling is to take place. Often, samples are split with the discharger for comparison purposes. Scheduled monitoring usually occurs when a violation has been identified during the unscheduled monitoring effort. Results may be used for enforcement. In most instances, composite samples are taken.

Demand monitoring is usually synonymous with some type of emergency at the treatment plant caused by a suspected or known illegal discharge or spill. The treatment plant operators may want to determine the characteristics of the discharge and attempt to identify its source or industry may be aware a spill has occurred and the DWQ wants to determine remedial measures to prevent plant upset.

The DWQ maintains a complete analytical laboratory which serves the needs of the DWQ's industrial monitoring program. The laboratory is an essential aspect of the DWQ's "total program" since it provides the mechanism for quick and reliable analysis of samples. An added benefit of having a competent chemistry laboratory is the credibility it establishes with the industrial sector. This is very important when it comes to solving

EPA-287 (Cin.)
(4-76)

problems related to discharges exceeding ordinance limitations. These solutions often cost the user time and money. Willingness to work with the DWQ toward a solution depends to a large degree on the credibility the DWQ has with the industry.

All samples received from the Surveillance Section field crew are logged in by the Chemistry Section chief chemist. The log serves as a record of when the sample was received, where and when it was taken, and what analyses must be performed. The sample is then processed immediately or stored for future analysis. The Chemistry Section follows analytical procedures outlined in three references. These are:

(a) "Manual of Methods for Chemical Analysis of Water and Wastes," published by the EPA Technology Transfer

(b) "Standard Methods for the Examination of Water and Wastewater," 14th Edition published by the American Public Health Association

(c) "Annual Book of Standards, Part 31, Atmospheric Analysis, 1975," published by the American Society for Testing and Materials (ASTM).

The laboratory maintains an internal quality control program to insure reliability of the data. The program involves routine tasks applied to all analytical tests as well as checks on all instrumentation and laboratory services. The laboratory participates in the EPA Region V Laboratory Quality Control Program where pre-analyzed samples are used to test accuracy of techniques. Quality control reference documents used by the laboratory include "Handbook for Analytical Quality Control in Water and Wastewater Laboratories" published by the EPA Technology Transfer Program, and the EPA document entitled "Methods for Chemical Analysis of Water and Wastes," also published by the Technology Transfer Program.

We believe that the success of our industrial pretreatment program depends upon many factors. The manner in which we enforce the regulations may have the greatest influence of any factor on the continuing success and viability of the program. It demonstrates the sincerity and honesty of all parties involved. For this reason, decisions regarding appropriate enforcement actions are made very carefully. The following factors are always considered when making a decision as to appropriate enforcement actions:

(a) Type of violation

(b) Frequency of violation

(c) Effects of the violation on the MSD system and receiving waters

(d) Past record of complying with ordinance and willingness to correct problems.

(e) History of discharge quality

A great deal of human judgment is included in decisions to implement enforcement actions. They must be fair, reasonable and supported by factual information. To date, the DWQ has not been forced to go to court to enforce the ordinance.

The MSD was established to perform a variety of purposes. One of these purposes was "to prevent the undue pollution of rivers, streams and water courses and other water" within its boundaries. For the MSD to accomplish this goal, the water quality of the surface water resources in our boundaries have to be monitored to allow identification of pollution not presently controlled as well as monitor trends or changes with time. Water quality data are necessary to determine the impact of efforts to eliminate pollution. The DWQ has the task of monitoring the water quality within the MSD boundaries. This is the second major element of the DWQ's program and the MSD's "total" program.

The MSD boundaries encompass nine bodies of water. The White River is the major river flowing through the District. It receives all runoff and direct discharges from the MSD treatment plant and other sources. Eight tributaries feed the White River. The Division has established 70 base stations on the White River and its tributaries.

The results of the baseline station sampling and analysis effort are used by the DWQ for the following purposes:

(a) To determine the suitability of the White River and tributaries for recreational use and the propagation of aquatic life;

(b) To monitor the effects of waste discharges including urban runoff on water quality;

(c) To track adherence to or violation of water quality standards;

(d) To determine patterns of pollution downstream from sources of pollution;

(e) To provide a source of field samples for Division research;

(f) To establish a baseline record of water quality for use in various studies, e.g., the 201 Facilities Plan; and

(g) To allow the DWQ to assess progress in improving water quality.

The DWQ is responsible for the cleanup of oil or chemical spills with the MSD jurisdictional area or in the White River watershed upstream of Muncie. The staff is on call 24 hours a day to respond. Spill containment and cleanup equipment is maintained, including booms, straw dams, pumps, and a trailerable boat.

The Division conducts in-house research projects in areas of direct concern to the MSD. Three research programs initiated by the Division are the Crop Uptake Program, the Fish Study and the Benthic Macroinvertebrates Study.

The DWQ began heavy metals analysis of the sludge generated by the MSD treatment plant in 1972. After one year of analysis, and in recognition that all sludge was being applied to farm land, the Division believed that the crop uptake study was necessary. The research program subsequently developed was intended to answer the basic question of whether sludge application to farm land would contaminate the soil and crops grown on that soil. The results would then be used to direct future sludge disposal programs.

A cooperative agreement was initiated with Purdue University's Agronomy School in October 1973. The agreement specified that the MSD would deliver digested sludge to Purdue's Herbert Davis Agricultural Center near Parker, Indiana, where the research would be conducted. Purdue agreed to perform soils analysis for fertilizer value and determine crop yields. The DWQ would perform the heavy metals analyses on soils and crop yields.

In the area of water pollution control, much emphasis in the past has been detection of water pollution through chemical analysis. One of the problems of monitoring water quality through chemical tests is the limited number of chemicals or compounds which can be economically tested for. Also, while there are standard chemical tests which indicate levels of pollution in a general sense, there is the very real possiblity of missing the regular or sporadic presence of a biologically toxic substance. By monitoring the biological communities found within an aquatic system, this type of problem can be detected and a solution sought. The thousands of creatures living in the aquatic system come in direct contact with those chemicals which may have been present at any one time within the water. Biological monitoring of water pollution is theoretically comparable to continuous twenty-four hour, 365 day per year sampling program of chemical parameters.

Populations of two groups of aquatic organisms, fish and benthic macroinvertebrates, are being monitored by the Division of Water Quality. Fish, an important recreational and food resource, are familiar organisms to most people. Benthic macroinvertebrates (animals which can be seen with the naked eye and have no backbone) are often overlooked by the public but are receiving attention from environmental scientists for their value as indicators of water quality. In the monitoring program, populations of fish and benthic macroinvertebrates are sampled periodically and the species and numbers collected are recorded. Anomalous changes in the population structures of these organisms are indicative of changes in water chemistry and provide the Division with a fairly reliable tool for assessing changes in water quality.

The benthic samples are being obtained and analyzed at thirty stations covering 100 miles of the West Fork of the White River and its tributaries. The objective of the program is to establish a macroinvertebrate baseline. Baseline is defined as periodic estimations of base station benthic community structure along with a continuing faunal survey. It is hoped that this work will lead to the recognition of a correlation between the presence or absence of particular species and water quality. The Division is striving to develop taxonomic keys for adult and larval macroinvertebrates so that the species can be properly identified. They are also developing a new method to sample these organisms.

The fish study involves the examination of metal concentrations in fish tissues taken at five stations on the White River and its tributaries within the Muncie city limits. The DWQ hopes to be able to determine ambient levels of selected heavy metals in the tissue. Such data may lead to guidelines for the regulation of trace elements in fish tissues.

The DWQ has two special studies under way. These studies were implemented to obtain additional information on the sources of metals entering White River watershed as well as the Muncie wastewater plant.

The Urban Sewer Study involves sampling sewers within the MSD which carry only domestic sewerage. The purpose of the study is to determine the amount of heavy metals generated by normal households in Muncie. Results can then be used as an aid in the regulation of industrial discharges.

Sources of metals in domestic wastewater include plumbing, natural levels in drinking water, and metals found in common household cleaning compounds and detergents. In addition, certain metals may enter a sewer system by infiltration of ground water and storm water.

Five locations are sampled each month. Grab samples are taken from manholes at each location. The samples are returned to the DWQ laboratory for analysis. Eight metals are run on each sample. They are chromium, lead, cadmium, nickel, copper, zinc, iron and manganese.

The DWQ calculated the following percentages of metal loadings to the wastewater treatment plant was from non-industrial sources:

Metal	Percent
Cr	2.3
Cu	33
Fe	49
Mn	25
Ni	11.5
Zn	15
Pb	8.6

The second special study being conducted by the DWQ involves monitoring the quality of storm runoff from various major parking areas in Muncie. The objective of this effort is to assess the impact of urban runoff on the water quality in the White River. Runoff from rainfall or snow melt is monitored at five major parking areas. Each lot was selected based on its accessibility and having a single isolated discharge point which does not carry sewage or industrial wastes. Samples are generally taken after an extended period of no runoff and when possible, are collected during the initial runoff period. This assures the worse case conditions will be monitored.

Governmental agencies that have the task of enforcing laws pertaining to pollution control also have the obligation to make sure that the industries affected by those laws are informed when they are proposed, when they become law, how they work, and to be available to answer any and all questions. If we are to effectively clean our environment, then we must work together as a team in a coordinated effort instead of just passing laws and then asking why they are not being enforced.

The Division of Water Quality and the industrial community of Muncie, Indiana, have set up an organization that puts both entities on the same side of the fence, working together instead of against each other. This organization in called "The Muncie Industrial and Commercial Clean Water and Waste Management Council." The purposes and membership are as follows:

A. Purpose

1. Relate industrial problems to the Division of Water Quality.
2. For industry to understand the Division's goals, responsibilities, and attitudes.
3. To work together for clean water.
4. To work together for grants in the area of pollution control.
5. To keep informed on the latest laws - local, state, and federal - that affect the Division of Water Quality and industry in Muncie.
6. To exchange technical information on:
    a. Testing procedures.
    b. Industrial techniques to abate pollution problems.
7. To work together on future problems and controls in the area of polution.
8. To help Muncie with respect to industrial development, i.e., type of community and industrial involvement in community ecological affairs.
9. To educate the public with respect to industries' role in pollution abatement.
10. To make sure that the environment will be available for future generations to use and enjoy as we did when we were children.

B. Members

1. Industrial and commercial establishments with water problems or possible water problems.
2. Division of Water Quality.
3. Indiana State Board of Health (Industrial Waste Section).
4. Muncie, Delaware Chamber of Commerce.

With this organization the community of Muncie will have input into the writing of new laws. When a new law is proposed on the federal, state, or local level, there is a period of time when anyone can voice or write their views or comments or suggested changes on the proposed law. If the people affected by the laws, either local or state enforcement agencies or the industrial community are not aware of the law, then there cannot be any input into its creation or revision to be a good and reasonable working law. This is an important part in our democratic way of life and needs to be practiced in the environment field as it is in the other areas of our life.

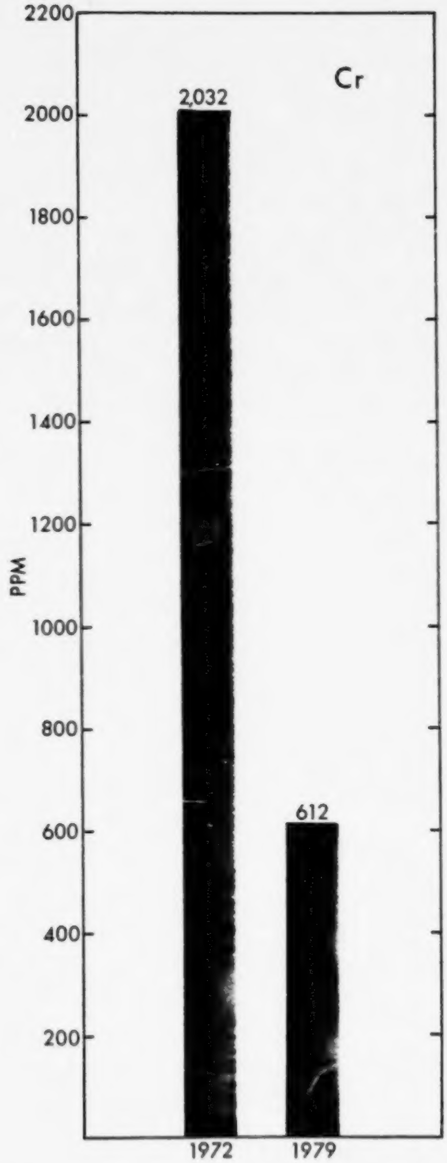
Communication is our most important factor in accomplishing any goal. If communication is lacking or almost non-existent in this area, then we will not effectively reach our goal of cleaning the environment.

To achieve these various goals on the local level several basic items are a necessity. One is a well equipped laboratory. The second is a well trained staff. The third is a good ordinance. The fourth is to allow this section of local government to exist and operate without political pressure. Without these four basic items, local control and clean up will not happen as it should. These are the general philosophies, and attitudes we have developed and instituted in our local program.

We have reduced the metals entering the treatment plant by various methods including but not limited to actual pretreatment. We have required industries to discontinue using Cr as an anticorossive agent in cooling towers. We have also required retaining walls around plating tanks so that drag out waste cannot reach floor drains. Actual pretreatment is not the only way to reduce metals entering a municipal plant.

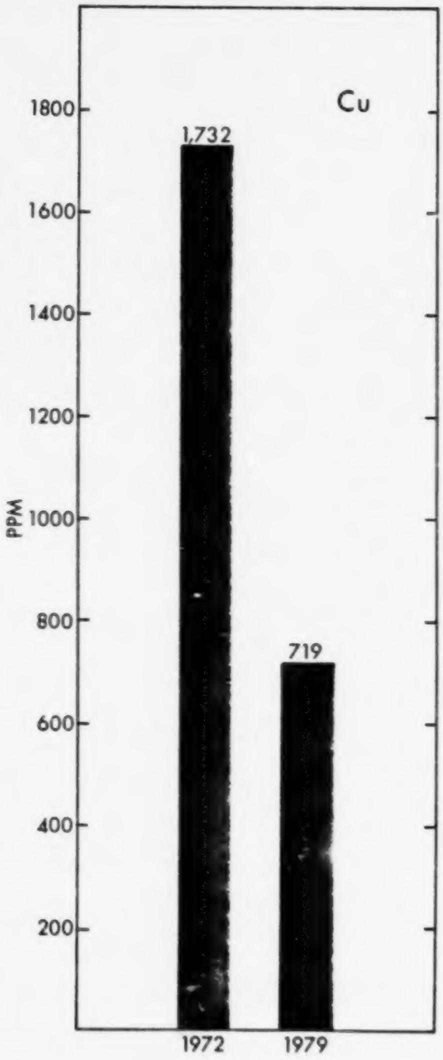
Since 1972 the metal concentration in Muncie's sludge has been reduced by the following: Cr, 70%; Cu, 59%; Ni, 58%, Pb, 91%; and Zn by 55%. See Table 1.

In conclusion it is our choice now whether we will communicate with each other in this problem area, or whether we will misinterpret or misunderstand what is needed, what can be accomplished, what can be afforded, and what we have to do together to have a clean environment for future generations to enjoy and use as we did when we were children.

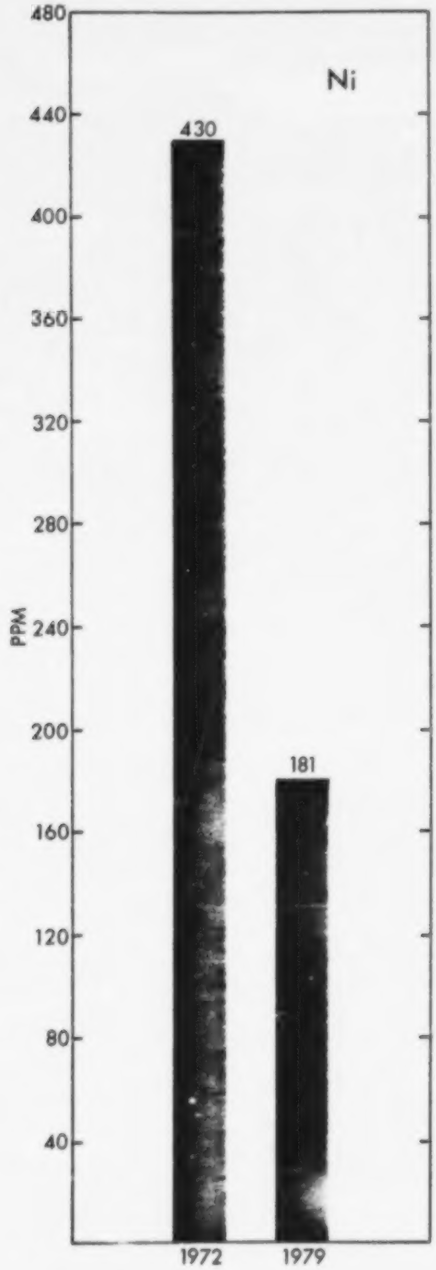


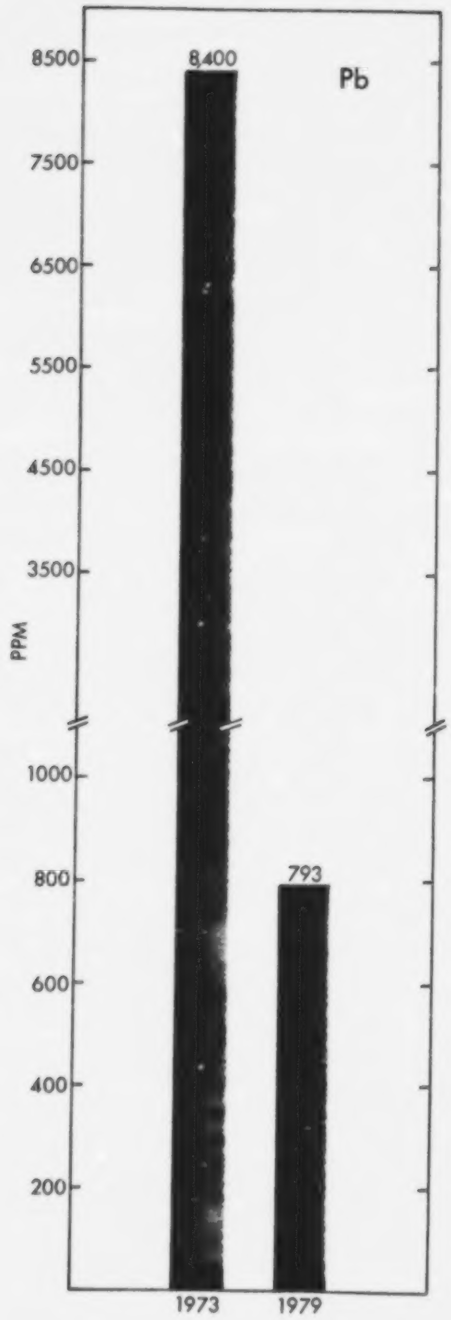
EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS

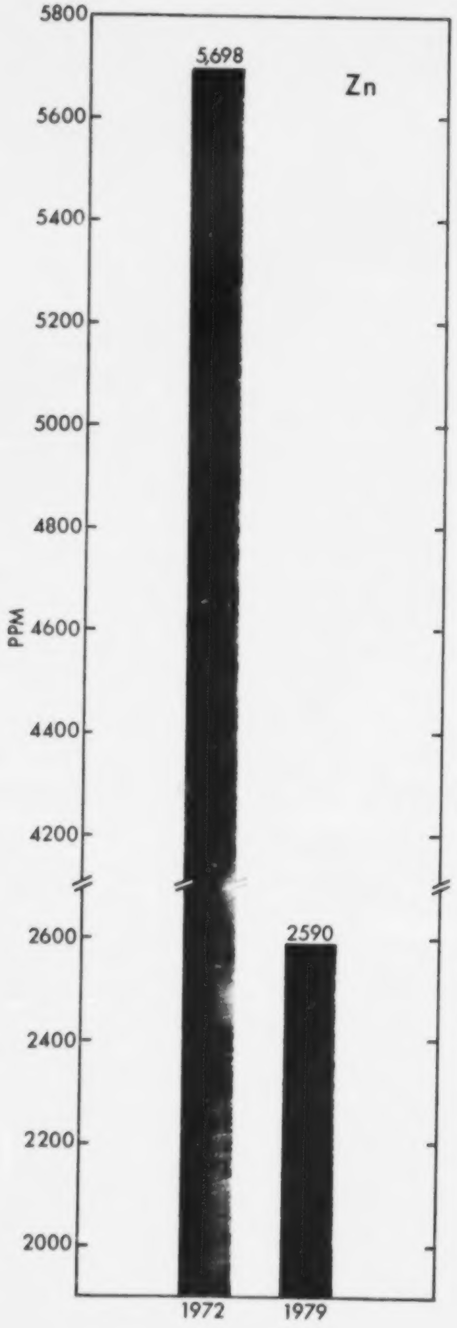


EPA-287 (Cin.)
(4-76)


Ni
PPM
480
440
400
360
320
280
240
200
160
120
80
40
430
181
1972
1979



8500
7500
6500
5500
4500
3500
PPM
1000
800
600
400
200
8,400
793
Pb
1973
1979


Zn
5800
5600
5400
5200
5000
4800
4600
4400
4200
2600
2400
2200
2000
PPM
5,698
2590
1972
1979

PB83-142315

THE CITY OF CHATTANOOGA INDUSTRIAL-MUNICIPAL PRETREATMENT PROGRAM

E. G. Wright, Superintendent
G. E. Kurz, Staff Engineer
D. A. Summers, Industrial Monitoring Supervisor

Chattanooga Interceptor Sewer System
Moccasin Bend Treatment Plant
Moccasin Bend Road
Chattanooga, Tennessee 37405

ABSTRACT

Faced with stringent 201 grant requirements to accomplish industrial waste control for protection of its 50 million dollar wastewater plant expansion, the City of Chattanooga has developed an innovative and comprehensive industrial pretreatment program to satisfy the conditions in its grant agreement. The goal of the strict compliance schedule in the grant agreement was to achieve control of industrial wastes by 1983 so that the plant expansion scheduled for completion then will be able to meet its NPDES permit conditions. The pretreatment program that evolved from the grant conditions is unique since it was developed simultaneously with the promulgation of EPA's General Pretreatment Regulations, and has been tailored to meet the requirements of EPA's National Pretreatment Strategy. The program developed by Chattanooga is additionally incorporating the National Categorical Standards now being issued by EPA and is one of the few cities to have sufficient data on "Consistent Removal" of toxic pollutants to apply to EPA for Local Removal Credits. The mass balance technique used by the City for developing local standards (as required by EPA regulation) has been adopted by the State of Tennessee and was recommended to the 41 cities in the State required to develop local programs. The results of the industrial waste survey, comprehensive sampling program, in-plant studies, and program costs will be of value to other municipalities required to develop local programs under 40 CFR 403, and to municipalities considering extending the benefits of local credits to their industries. The significance of cooperation with, and by regulated industries is highlighted.

INTRODUCTION

EPA proposed in February 1977 a comprehensive, unified National Strategy for regulating industrial discharges. The overall impact of this regulation (and its extensions, the National Categorical Standards) may be more significant in terms of public and private dollars than any other program to come from the Clean Water Act. While large POTW's have generally been aware for some years that unregulated industrial discharges cannot be tolerated, many small and medium sized municipalities (including Chattanooga) have not been aggressive in this area. One of the most valuable byproducts of this current round of regulatory activity has been to galvanize these municipalities into taking action to examine their systems, and to evaluate and optimize operation of their POTW's. This paper will discuss the effects of the pretreatment regulations on the City of Chattanooga. Hopefully, the lessons-learned reported in this case history can be intelligently applied to support those parts of the National Strategy that reflect insight and wisdom and modify those parts that tend to degrade the positive effects of the program.

CASE HISTORY

Plant Expansion

Presently, the city operates a 42 MGD (design) air activated sludge plant at Moccasin Bend, and a smaller 3.5 MGD activated sludge plant at Brainerd which will be phased out through the 201 plan. The system serves a community where half the flow, 65% of the BOD, and 75% of the COD load is from industry. The larger plant was expanded to its present size and capacity in 1971 and was provided with a Zimpro wet-air oxidation facility to treat the secondary waste activated sludge. This unit operated unsatisfactorily for about two years before the problems of odor and high organic recycle became unbearable. At the time of its shutdown, part of the operational problems of the Zimpro system were attributed to the high industrial waste load to the main plant. At present, all of the waste activated sludge is discharged directly to the Tennessee River under interim NPDES standards.

Hydraulic and organic overloads, wide fluctuations of influent characteristics, and the lack of an acceptable disposal method for the secondary sludge were problems evaluated through the 201 process. Pilot plant studies led the consultants as well as the process vendors to the conclusion that pre-treatment and source control would be necessary before any process could be made to operate dependably. When these reports were issued to the regulatory agencies,they agreed that a strong and aggressive sewer use ordinance was needed. Therefore, the city was required to develop and implement a new and comprehensive ordinance as a special condition to the Step II Grant.

The first ordinance to satisfy the Step II Grant was passed in January 1977. The list of pollutants which would be controlled by the ordinance was developed utilizing the proposed 208 basin plan standards and the State of Tennessee Discharge Permit. This ordinance regulated 32 different pollutants. The levels were based on the BPT (Best Practicable Treatment) levels which were being imposed on direct dischargers by the State of Tennessee under its own permit system at that time and shown in Table 1.

That ordinance was adopted by the City Commission over the objections of the industrial community. At that time, there was a definite communications problem which led to misunderstandings with respect to the goals of the ordinance. However, the City Commission promised the Chattanooga

Manufacturer's Association (the principle organization of affected industries) that the City would give every consideration possible to their requests to review the standards, and to determine whether or not a variance procedure for granting exceptions to the standards would be possible.

TABLE 1. 1977 INDUSTRIAL EFFLUENT LIMITATIONS

Parameter	Average Concentration (Mg/1)	Maximum Concentration (Mg/1)
Biochemical Oxygen Demand	*	-
Chemical Oxygen Demand	*	-
Suspended Solids	*	-
Antimony	5.0	8.0
Arsenic	1.0	1.5
Barium	35.0	50.0
Boron	55.0	80.0
Cadmium	1.0	1.5
Chromium-Total	0.5	1.0
Cobalt	10.0	15.0
Copper	1.0	1.5
Cyanide	1.0	1.5
Fluoride	45.0	70.0
Iron	45.0	70.0
Lead	1.0	1.5
Magnesium	10.0	15.0
Manganese	1.0	1.5
Mercury	0.1	0.2
Nickel	3.0	4.5
Phenols	10.0	15.0
Phosphorus	10.0	15.0
Selenium	0.1	0.2
Silver	1.0	1.5
Strontium	30.0	50.0
Tin	10.0	15.0
Titanium	3.0	5.0
Zinc	2.0	3.5
Total Kjeldahl Nitrogen	60.0	90.0
Oil and Grease (Hexane or Petroleum Soluble)	100.0	150.0
Total Dissolved Solids	5,000.0	7,500.0
M.B.A.S. (Non-Biodegradable)	5.0	8.0
Organic Toxicants	N.D.A.	N.D.A.

*Depends on plant design.

Shortly after the adoption of the 1977 ordinance, the City technical staff developed a new plan for setting ordinance limits based on protecting plant processes and the environment. The main problem with the 1977 standards was that they were not the result of a logical thinking process designed to satisfy the requirements specified in Section 307 of the Clean Water Act; i.e., 1) to protect the treatment plant processes, 2) to prevent pass-through of inadequately treated pollutants, and 3) to protect the sludge from contamination by pollutants to a degree that the least costly environmentally safe disposal means could not be used. Rather, the limits that were used were only based on an estimate of industrial treatment capabilities. In that regard, the 1977 standards closely resembled the present EPA approach for the development of National Categorical Standards, and therefore the local standards suffered many of the same defects and shortcomings as the EPA National Standards.

Program Development

As part of the 201 process, a strict timetable of compliance milestones was attached to the Step II Grant Agreement by the State of Tennessee. This timetable has since been modified by the State Director to conform to the requirements in the General Pretreatment Regulations and is now included in all municipal NPDES Permits issued by the State. Table 2 shows all the steps in a typical NPDES permit. The Chattanooga program has minimally satisfied all the requirements except for the last two steps which require a public presentation and formal application for approval.

As NPDES permits are reissued by the State Director, all municipalities in Tennessee must accomplish Activities 1, 3, and 4, (industrial survey, develop protection criteria, and adopt an acceptable sewer use ordinance). Additionally, the State estimates that 41 cities will have to perform all 13 activities for a complete program.

The survey of various lists of industries in Chattanooga resulted in a list of 340 industries thought to be capable of discharging a nondomestic waste to the sewer system. These industries were contacted by letter and required to complete a permit application which included a wastewater characterization for the 32 pollutants in the ordinance. The application also included a questionnaire concerning waste producing processes. This list did not include garages or other small commercial establishments, unless they had SIC Codes listed in the EPA National Pretreatment Strategy.

The completed application ultimately resulted in 182 permits being issued to 130 firms (some with multiple discharges) on February 1, 1979. However, it was necessary to review the ordinance standards as promised by the Commission, and possibly revise those standards prior to issuing the permits. Changes to the ordinance standards were based on developing two tables of limits. One table would list the most critical concentration for a particular pollutant chosen by comparing plant inhibition data (1), and NPDES Permit requirements. This process would result in "protection criteria" to satisfy Section 307 of the Act. This process is illustrated in Figure 1.

TABLE 2. POTW NPDES COMPLIANCE SCHEDULE

Activity Number	Activity
1.	On or prior to ______________, the permittee shall submit the results of an industrial user (IU) survey in accordance with 40 CFR 403.8 (f) (2) (i), including any IU's covered under Section 301 (i) (2) of the Act. As much information as possible must be obtained relative to the character and volume of pollutants contributed to the POTW by the IU's.
2.	On or prior to ______________, the permittee shall submit a technical report acceptable to the Tennessee Division of Water Quality Control which accurately characterizes the wastewater influent to the POTW in terms of flow, compatible and incompatible pollutants as well as upsets and/or loading variations.
3.	On or prior to ______________, the permittee shall submit a technical report acceptable to the Tennessee Division of Water Quality Control which establishes the protection criteria for the POTW in terms of interference, inhibition and pass-through. Thus, this report must specify influent limitations at the POTW for prohibited pollutants (as defined by 40 CFR 403.5) contributed to the POTW by the IU's.
4.	On or prior to ______________, the permittee shall obtain adequate legal authority to administer a pretreatment program by adopting a Sewer Use Ordinance (SUO) acceptable to the Tennessee Division of Water Quality Control for the control of discharges to the sewerage system of the City of __________________________ by all IU's.
5.	On or prior to ______________, the permittee shall submit a summary report relative to the progress and direction of the POTW Pretreatment Program. The scope of this report must address two items: (a) Revisions to NPDES pretreatment compliance schedule (on the basis that the POTW is justified in not being required to have a complete pretreatment program or more time is needed to complete activities than originally anticipated). (b) Amendments to the pretreatment grant, if applicable.
6.	On or prior to _____________, the permittee shall submit a technical report acceptable to the Tennessee Division of Water Quality Control which accurately accounts for all pollutant sources. This report must contain a pollutant-by-pollutant mass balance analysis of the sewerage system showing the correlation of the industrial contributions with that of actual influent POTW conditions.

TABLE 2 (Continued)

Activity Number	Activity
7.	On or prior to _____________, the permittee shall submit a technical report acceptable to the Tennessee Division of Water Quality Control which explains the design of a monitoring program necessary to implement the POTW pretreatment program and to carry out the directives of the SUO.
8.	On or prior to ___________, the permittee shall submit a list of monitoring equipment required by the POTW to implement their pretreatment program and a description of municipal facilities to be constructed for the monitoring or analysis of industrial wastes.
9.	On or prior to ____________, the permittee shall submit an evaluation of the financial programs and revenues sources necessary to implement their pretreatment program and to carry out the directives of their SUO which is acceptable to the Tennessee Division of Water Quality Control.
10.	On or prior to _____________, the permittee shall submit a detailed description of the methodology used to issue permits to the IU's. This methodology must be consistent with the provisions of their SUO and acceptable to the Tennessee Division of Water Quality Control. (Where contracts or joint powers of agreement are used substitute the appropriate term in place of the word, "permit").
11.	On or prior to _____________, the permittee shall issue all IU permits consistent with the provisions of their SUO.
12.	On or prior to 30 days prior to submission of the POTW Pretreatment Program the permittee shall make available to the public a copy of their draft submission. (The permittee must comply with the requirements of 40 CFR Part 403.9 (d)).
13.	On or prior to ____________, the permittee shall submit a request for pretreatment program approval (and removal credit allowances approval, if desired).

Exception to Pretreatment Program Requirements

If the industrial user survey required by Activity 1 of the pretreatment compliance schedule demonstrates that the POTW has no industrial user nor will have an industrial user via Section 301 (i) (2), then the permittee will be required to satisfy only Activities 1, 3 and 4 of the pretreatment compliance schedule.

The second table of standards (and more significant from an enforcement standpoint) specified what levels could not be exceeded by a given industrial discharge at the point it entered the City Sewer System. It is interesting to note that these types of standards were called "optional" in a recent EPA model ordinance. This, however, is misleading. Such standards are the only practical means of enforcing discharge permits. By way of illustration, notice that there is nothing "optional" about the standards in NPDES permits for direct dischargers.

Each pollutant limit was developed through a mass balance of the pollutant in the sewer system. The total load reported in the industrial permit applications was compared to the observed pollutant load at the treatment plant influent. A computer program was developed to perform these summations and to account for the inventory of pollutants. Also, the observed pollutant load at the influent was compared to the first table of the treatment plant influent standards (the protection cirteria). Industrial Discharge Standards were selected for those pollutants which were causing or close to causing violations to the POTW influent standard. The actual numerical limits were selected by a combination of considering dilution in the sewer system by "backing a standard up the pipe," and inspection of data from all dischargers of the pollutant under consideration. In most cases it was possible to select a cut-off point by this process for those industrial dischargers which had high concentrations due to poor housekeeping and/or wasteful processes, and who were causing most of the violations at the treatment plant. The remaining standards were negotiated with the State Director and EPA. These standards are more stringent than would have been calculated by the above procedure; however, it was understood in the negotiations that as a better data base was developed, and compliance with the plant's NPDES standards was achieved, the discharge standards could be adjusted if found to be too stringent. Controlling the discharge of these pollutants also provides a factor of safety for synergistic effects that may be causing some of the plant operating problems.

To protect industry from having to install pretreatment that may be designed for more stringent standards than necessary, the City negotiated two major timetables for industrial compliance. The first schedule which must be completed by January 1, 1981, covered all pollutants currently exceeding the plant influent standards as shown in Table 3. The second schedule must be completed by January 1, 1983, and covers the remaining pollutants in the Table of Industrial Discharge Standards. With these factors in mind, a revised set of industrial effluent limits were developed. The limits shown in Table 4 have been approved by the State and EPA and are considered adequate in controlling the industrial discharges to the sewer. Note that numerous pollutants have been dropped from this table. This was due to no control currently being warranted because of low loadings presently experienced at the treatment plant. However, the City has reserved the right to apply more stringent limits, or to add additional limits, should this be necessary sometime in the future.

			ORDINANCE PROTECTION CRITERIA	
POLLUTANTS	NPDES PERMIT DAILY MAXIMUM (mg/1)	INHIBITION THRESHOLD (mg/1)	24 HOUR FLOW COMPOSITE (mg/1)	INSTANTANEOUS MAXIMUM (mg/1)
Arsenic	1.0	0.1	0.05	0.1
Copper	0.4	1.0	0.4	0.8
Nickel	3.0	1.0	0.5	1.0
Silver	0.05	5.0	0.05	0.1

Figure 1. Examples of the Methodology for Selection of the Most Critical Limits for Ordinance Standards.

TABLE 3. CRITERIA TO PROTECT THE TREATMENT PLANT

Parameter	Influent Limit
Aluminum (dissolved)	15.00 mg/1
Antimony	0.50 mg/1
Arsenic	0.05 mg/1
Barium	2.50 mg/1
Boron	1.00 mg/1
Cadmium	0.01 mg/1
Chromium-total	1.50 mg/1
Cobalt	5.00 mg/1
Copper	0.40 mg/1
Cyanide	0.05 mg/1
Fluoride	10.00 mg/1
Iron	5.00 mg/1
Lead	0.10 mg/1
Manganese	0.50 mg/1
Mercury	0.015 mg/1
Nickel	0.50 mg/1
Phenols	1.00 mg/1
Selenium	0.005 mg/1
Silver	0.05 mg/1
Titanium-dissolved	1.00 mg/1
Zinc	2.00 mg/1
Total Kjeldahl Nitrogen	45.00 mg/1
Oil & Grease	25.00 mg/1
Total Dissolved Solids	1,875.00 mg/1
BOD	*
COD	*
S. S.	*

*Dependent on design capacity of treatment process

EPA-287 (Cin.)
(4-70)

TABLE 4. 1978 INDUSTRIAL EFFLUENT LIMITATIONS

Parameter	Maximum Concentration Mg/1 (24-hour Flow Proportional Composite Sample)	Maximum Instantaneous Concentration Mg/1 (Grab Sample)
BOD	*	-
COD	*	-
TSS	*	-
Arsenic	1.00	2.00
Cadmium	1.00	2.00
Chromium-total	5.00	10.00
Chromium-Hexavalent	0.05	0.10
Copper	5.00	10.00
Cyanide	2.00	4.00
Lead	1.50	3.00
Mercury	0.10	0.20
Nickel	5.00	10.00
Selenium	1.00	2.00
Silver	1.00	2.00
Zinc	5.00	10.00
Oil & Grease (Petroleum and/or Mineral origin)	100.00	200.00

A comparison of the ranking of the Chattanooga standards with standards for metals in other municipal ordinances from a study by Dietz (2) is shown in Figure 2. For these metals it can be seen that the Chattanooga standards are quite liberal. Yet, based on our research, they are sufficient to protect the treatment works. The significance is the methodology. The limits for any given plant are subject to variation due to local conditions.

Locally, the impact of the new standards may be seen in Table 5, showing a significant reduction in the number of industries which would be required to pretreat, and that the total flow which was subject to pretreatment in the old standards has been reduced by two-thirds. It is estimated that required capital expenditures will be cut in half.

The plant technical staff has determined that by the time industries will have to begin compliance activities for the 1983 standards, several major changes in the environmental situation will have occurred. First, most of the National Categorical standards will have been published by EPA as shown in Figure 3. As they are promulgated, they will administratively supercede Chattanooga's ordinance standards for the pollutants and industries in each National Standard. (Industries subject to National Standards, however, will still have to comply with the City standards if the local standards are more stringent and/or if the ordinance controls pollutants not covered by the National Standards). It should be clear from the previous dissusion that the National Standards are not needed for environmental protection but are included in Chattanooga's program solely because of EPA administrative requirements.

Second, the data base at the plant on these pollutants is continually expanding and there should be sufficient information available prior to the first compliance date in the 1983 schedule to either confirm or revise the industrial standards for pollutant levels that are not violating the plant influent levels at the present time. This data base is being supplemented by information generated from the "local credits" sampling program.

With the industrial and plant sampling programs well under way, the monitoring staff conducted a thorough residential/commercial sampling program to identify the pollutant loadings associated with those contributors. A one-month residential and commercial wastewater survey was initiated in July 1978. The samples were analyzed by the city laboratory for all parameters required by the ordinance. Table 6 shows the results of that sampling.

The values shown compare well with those previously listed in the literature. Also, no significant differences are noted for samples obtained from a purely residential area to those collected from a mixture of residential and commercial wastewater.

Because of concerns previously raised by industry, the POTW staff made every effort to insure that those concerns were fairly addressed and that the industrial community was involved in the decision making process. This was accomplished through presentations to the Wastewater Appeals Board (created in the 1977 ordinance) and to the Environmental Committee of the Chattanooga Manufacturer's Association (CMA). The five member Board which was made up of representatives of the industrial, economic, engineering and legal segments of the community, and the CMA, worked closely with the POTW staff for almost a year to develop the ordinance revisions. These were finally drafted and accepted shortly after the long awaited Pretreatment Regulations were published in June 1978. No objections were made to the proposed standards once the mass balance study was completed and reported to the CMA Environmental Committee. The main reason for this was that it was obvious to all concerned that the City was only requesting controls and limit levels that were logically related to plant operation and environmental protection. Additionally, a modified version of the exception clause provides latitude to the Wastewater Appeals Board for flexibility in granting relief from specific standards. To date, only two firms have requested this type of relief. Both submitted reports, as required by the ordinance, which certified that good management practices for pollution control were in effect. Various other factors such as impact on the POTW, whether the exception was for toxic pollutants, the age of the equipment, water conservation, etc., were reviewed on a case-by-case basis by the Board.

The final draft revision of the ordinance was easily passed by the City Commission when letters of endorsement were presented from the CMA, the State of Tennessee, Region IV EPA, and the Appeals Board. This unanimous approval prompted one Commissioner to remark that to have gotten agreement from such diverse parties was, "only a little short of miraculous." This firmly underscored the value of prior coordination with all interested groups. The ordinance is in the Appendix.

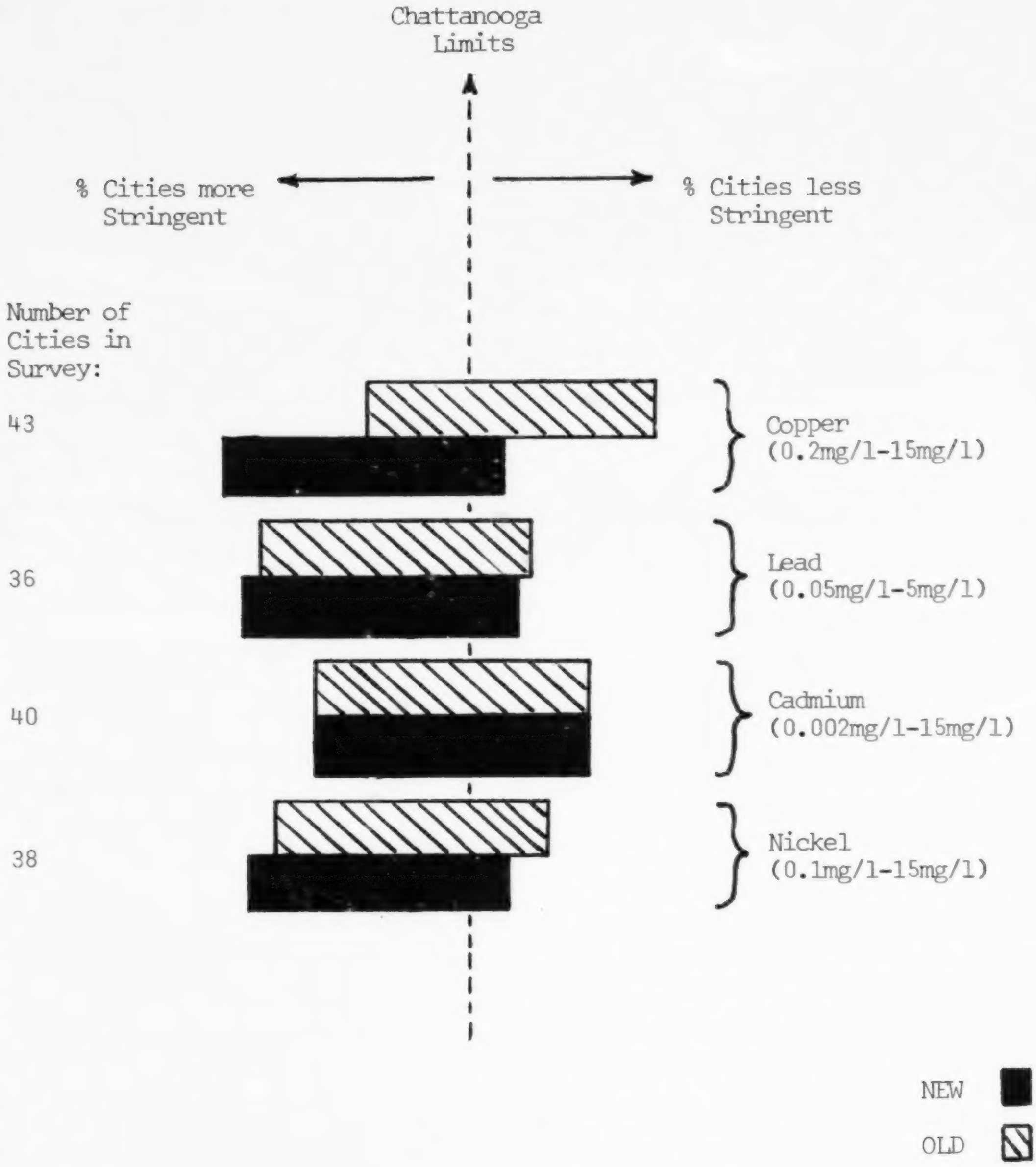


Figure 2. Graphical Comparison of Chattanooga Standards With Other Cities.

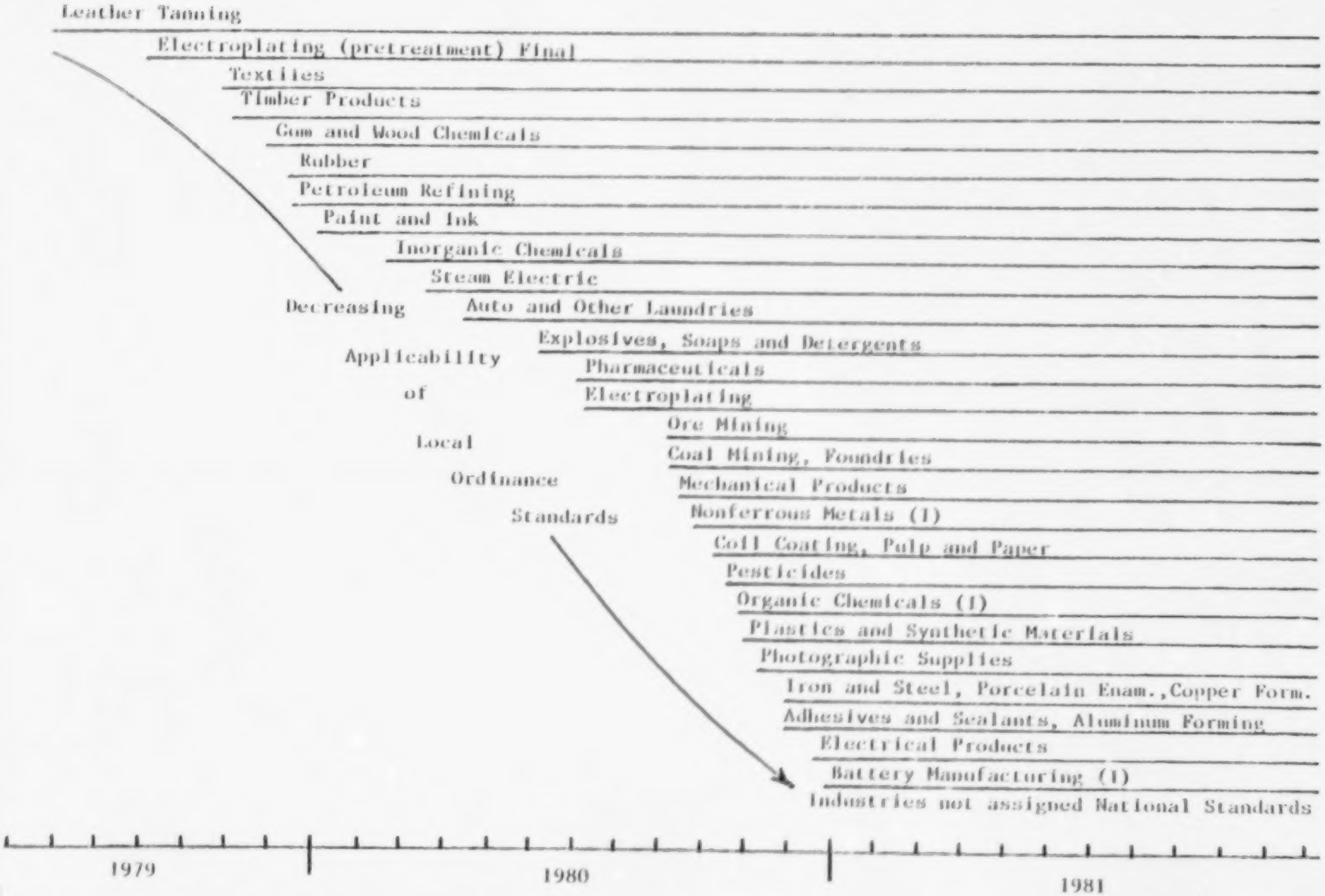


Figure 3. Relationship between City Standards and Schedule for National Standards

TABLE 5. REDUCTION OF PRETREATMENT REQUIREMENTS

	Number of Industries Requiring Pretreatment		Flow Requiring Pretreatment (MGD)	
Pretreatment required for:	Old Limits	New Limits	Old Limits	New Limits
Metals only	53	15	7.0	0.2
Metals (Oil and Grease)	31	10	2.6	0.1
Oil & Grease only	13	34	0.2	2.7
TOTAL	97	59	9.8	3.0

TABLE 6. RESIDENTIAL AND COMMERCIAL WASTEWATER CHARACTERISTICS

	Concentration(Mg/1)	
Parameter	Residential	Residential/Commercial
BOD_5	250.000	240.000
COD	600.000	520.000
TSS	290.000	280.000
NH_3-N	21.000	23.000
TKN	35.000	26.000
Phosphorus	10.000	11.000
Fluorides	3.100	2.300
Surfactants(MBAS)	9.800	10.800
Aluminum	1.100	1.020
Antimony	0.001	0.001
Arsenic	0.001	0.001
Barium	0.051	0.046
Boron	0.210	0.300
Cadmium	0.002	0.002
Chromium	0.011	0.024
Cobalt	0.001	0.001
Copper	0.120	0.100
Cyanide	0.010	0.010
Iron	2.100	1.700
Lead	0.026	0.028
Magnesium	6.100	5.900
Manganese	0.039	0.050
Mercury	0.001	0.001
Nickel	0.019	0.015
Phenols	0.020	0.040
Selenium	0.001	0.001
Silver	0.008	0.016
Strontium	0.029	0.049
Tin	0.010	0.010
Titanium	0.240	0.370
Zinc	0.400	0.330

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD, BEGIN SECTIONS HERE
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
PAGE NUMBER

The City staff feels that the revised limitations placed on the industrial discharges to the system will adequately protect the treatment plant while requiring no unnecessary treatment by industry. This, therefore, will satisfy the goals of the Clean Water Act. It should not be inferred that the users "welcomed" these new restrictions. However, they at least understood the importance of the City standards which were designed to protect the plant operation.

Current Program

Staff and Organization

The present staff is organized as shown in Figure 4. This structure should have sufficient flexibility to expand or change as the program matures through the major stages of data gathering, pretreatment enforcement, verification monitoring, and updating of standards and rate schedules. While most of the original end-of-pipe sampling was performed by two two-man crews, only one crew is presently conducting verification sampling at this time due to personnel turnover. A second crew will be activated soon to enable the program to sample all permitted discharges once a year as required in the EPA program and to maintain the same level of responsiveness for verification sampling and local credits sampling.

Permit and Ordinance Enforcement

The Industrial Wastewater Discharge Permits are the most visible extension of the Industrial Waste Ordinance and the authority of the Superintendent. The permit sets forth self-monitoring requirements for each industrial discharger as well as a compliance schedule for pretreatment if standards are exceeded. A permit may also contain other special conditions depending on the nature of the discharge. Ninety-five (95) of the first City permits had some kind of pretreatment compliance schedule.

Monitoring industrial discharges for compliance is a critical part of the program, yet it would have been impossible to carry out adequately with the limited City staff. Therefore, it was decided that the periodic monitoring would be carried out by the affected industries, with the City conducting annual unannounced verification monitoring as described in 40 CFR 403. While this sounds like "leaving the fox to guard the hen house," in reality no cases of data falsification have been detected. Additionally, many industries seem to have become more conscious of, and responsive to their wastewater violations. Some of these violations were a result of poor housekeeping. Eleven companies that have corrected their housekeeping problems are now in compliance.

The decision to require self-monitoring for a given pollutant is based on whether that pollutant is present at levels above the ordinance limit, at levels below the ordinance limit but above domestic levels, or at levels below domestic waste. Monitoring is classified in categories for the purposes of enforcement, surveillance, or not required, respectively. In addition, surcharge monitoring may be required for BOD_5, COD, and Suspended Solids.

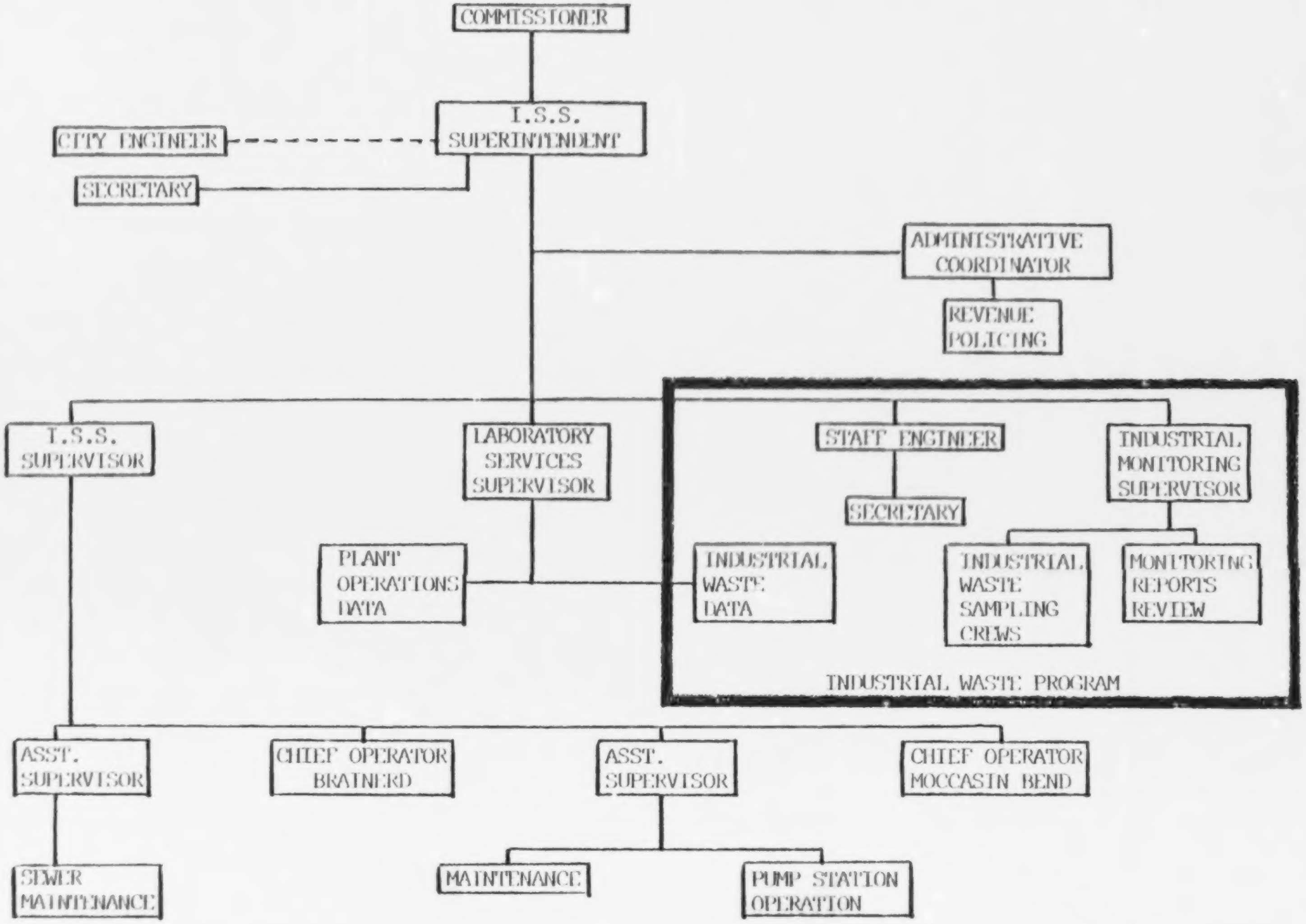

COMMISSIONER
I.S.S. SUPERINTENDENT
CITY ENGINEER
SECRETARY
ADMINISTRATIVE COORDINATOR
REVENUE POLICING
I.S.S. SUPERVISOR
LABORATORY SERVICES SUPERVISOR
STAFF ENGINEER
SECRETARY
INDUSTRIAL MONITORING SUPERVISOR
PLANT OPERATIONS DATA
INDUSTRIAL WASTE DATA
INDUSTRIAL WASTE SAMPLING CREWS
MONITORING REPORTS REVIEW
INDUSTRIAL WASTE PROGRAM
ASST. SUPERVISOR
CHIEF OPERATOR BRAINERD
ASST. SUPERVISOR
CHIEF OPERATOR MOCCASIN BEND
SEWER MAINTENANCE
MAINTENANCE
PUMP STATION OPERATION

Figure 4. Organization Chart

Each class of monitoring has an associated frequency depending on the size of the discharge as shown in Figure 5.

Forms were developed by the staff for making monitoring reports, with the method of analysis specified on the form for each parameter (as shown in the Appendix). This eliminated questionable or inadequate "kit" type analysis. The City also conducts monitoring at the request of a discharger to verify that compliance standards have been achieved. Monitoring can be requested by a discharger in addition to self-monitoring but not in lieu of permit requirements, and this monitoring is charged to the industry at a base rate set in the surcharge ordinance.

Local Credits Monitoring

The administrative concept of local credits first appeared in 40 CFR Part 128, which preceded Part 403. This concept was only allowed to be used in those cases where "substantial" removal was documented and when the POTW was actually designed to remove the pollutant under consideration. Shortly after the publication of Part 403 in June 1978, the City of Chattanooga initiated a program as described in Section 403.7 for gathering data to support a local credits request for the Moccasin Bend Treatment Plant. That section defines consistent removal as "reduction in the amount of a pollutant or alteration of the nature of a pollutant in the influent to a POTW to a less toxic or harmless state in the effluent which is achieved by the POTW in 95% of the samples taken when measured according to the procedures set forth in Section 403.7 (c)(2)." Essentially, these procedures were directed towards obtaining samples representative of yearly and seasonal conditions, and require a minimum of 12 discrete influent and effluent samples to be composited each day for three consecutive days each sampling period.

The City sampling crews have collected samples for information on consistent removal during seven quarterly sampling periods with each period seven days long and having 24 sample collections per day. Four locations were sampled each hour as shown in Figure 6 which resulted in a total of 96 discrete samples collected per day. Effluent samples were taken nine hours later than influent samples to allow for the plant hydraulic detention time. The sampling and analysis was documented exactly in accordance with the procedures outlined in Section 403.12 (n) for 31 pollutants of interest.

Under the current procedures and definitions in 40 CFR 403, the City could not request local removal credits. Each toxic pollutant had at least two days that showed no removal or a higher level of pollutant in the effluent than in the influent. This meant that the 95% confidence level could not be met to verify "consistent removal."

Failure to achieve this "consistent removal" by the EPA standards at the Moccasin Bend Plant was attributed to the fact that the seven-day sampling period did not allow for the 21-day detention time in the anaerobic digesters. Since most of the toxics discussed in the Chattanooga study were metals, and therefore conservative in nature, it is expected that the recycle load from the digester caused fluctuations in the metal concentrations downstream from the influent sampling point that were unrelated to the

Industrial Discharge Volume	Sample Type	SAMPLING INTERVAL					
		Weekly	Semi-Monthly	Monthly	Quarterly	Semi-Annually	Annually
Greater than 100,000 gpd	E	X					
	SV			X			
	SC					X	
100,000 gpd to 50,000 gpd	E		X				
	SV				X		
	SC						X
50,000 gpd to 10,000 gpd	E		X				
	SV					X	
	SC						X
10,000 gpd to 800 gpd	E			X			
	SV						X
	SC						X
Less than 800 gpd	E				X		
	SV						X
	SC						X

Figure 5. Monitoring Schedule for Enforcement (E), Surveillance (SV), and Surcharge (SC) Reports

influent load on the day sampled. Nonetheless, averages of the data from this study and averages of 130 additional days show an overall removal of these pollutants. Additionally, metals have been shown to accumulate in the primary sludge solids indicating removal of metals from the effluent.

The experience of the local credits program at Moccasin Bend is not unique and the situation in Chattanooga would likely be repeated in virtually any plant having a unit process with a detention time longer than the required sampling period. "Negative removals" also have showed up in EPA's study of 40 POTW's (3). Yet, many of these plants would also be able to show long term removals. The problem of getting permission to apply for local credits has been complicated by: 1) the requirement to have an approved pretreatment program; 2) the requirement to have the year-long local credits study completed by the time a POTW applies for its program approval (or be forced to wait until its permit is reissued); and 3) the unresolved question of periodic reverification of removals. These difficulties make it unlikely that any POTW would succeed in demonstrating removals or that many would even attempt to take advantage of the relief granted by Congress in the 1977 Clean Water Act Amendments. This statement was verified by the negative reaction to local credits expressed by POTW managers at the recent AMSA National Pretreatment Conference. The problem seemed to be one of how EPA defined the program rather than whether or not removals were actually being achieved.

Recently the draft revisions of 40 CFR Part 403 became available. These revisions published in October 1979 provided for an alternate methodology to calculate removals based on 12 monthly samples. The City staff feels that the 47 days of sampling checked so far provide a superior data base for its local credits request. Also, discussions with EPA's Office of General Counsel have indicated that the City may be able to use the data collected on the "raw" and "treated" sample as a basis to claim removals when the new plant expansion is complete. The reason for this is that this set of data would be more representative of a plant which has a system to dispose of the waste activated sludge. Removals calculated by this revised method are based on an average of the lowest 50% of the data points or the lowest 6 data points (whichever number of points is greater). If there are less than 8 usable samples, the Approval Authority may approve alternate means to calculate "consistent removal."

The results for 13 of those pollutants which were on the list of 129 toxics are shown in Table 7. Based on these results, the City has made the first application in Region IV for verification of consistent removal. The State of Tennessee has already approved this request. If Part 403 is modified as proposed, then the City will be able to base a request for local credits on the consistent removal already documented without going through another lengthy technical review. Time is most critical at this point because industries are already having to begin planning for pretreatment design and they need to know as soon as possible what credits will be available for the program to be of any worth. The foregoing demonstrates that the City of Chattanooga is strongly committed to local credits. However, it should be

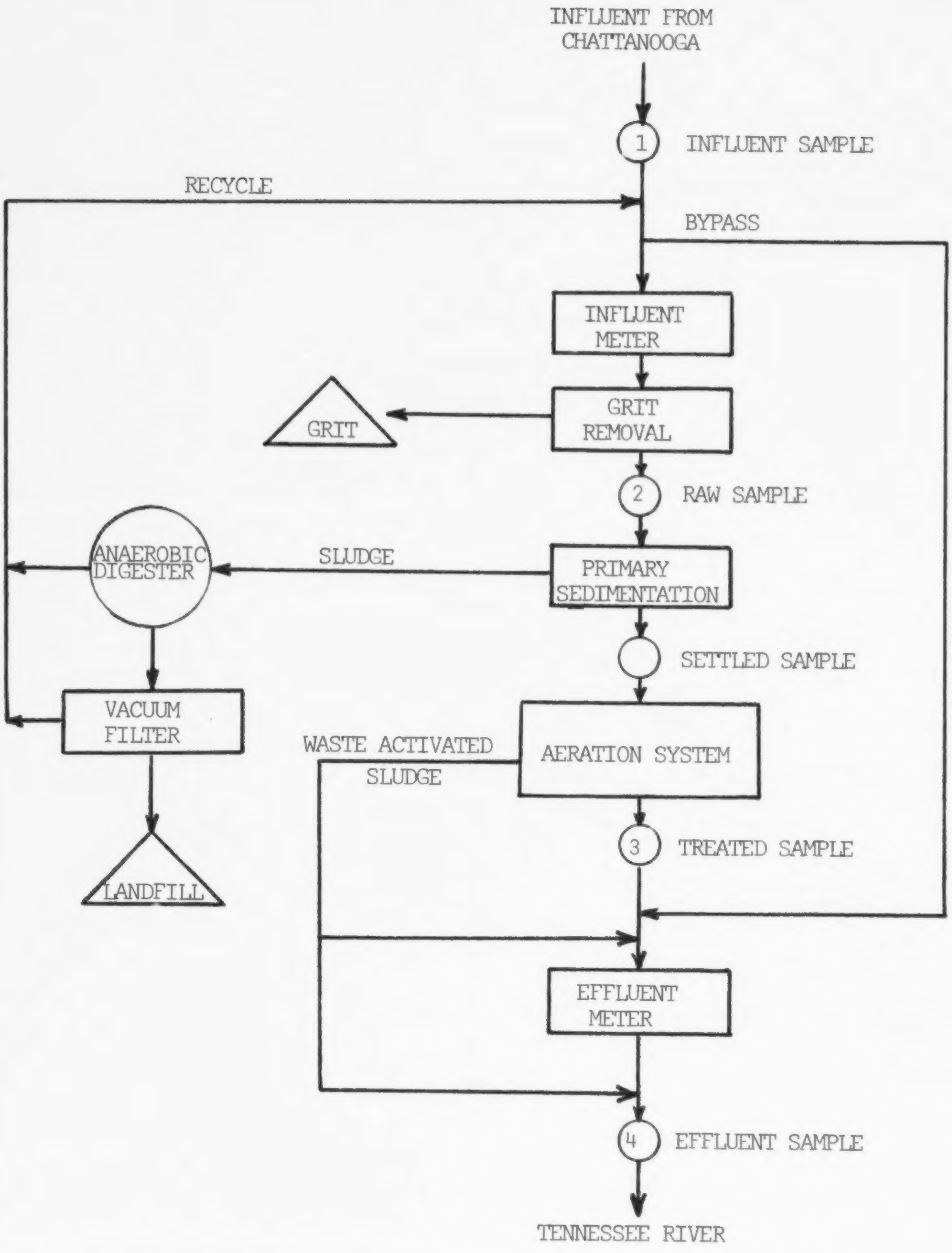

INFLUENT FROM CHATTANOOGA
1
INFLUENT SAMPLE
RECYCLE
BYPASS
INFLUENT METER
GRIT REMOVAL
GRIT
2
RAW SAMPLE
ANAEROBIC DIGESTER
SLUDGE
PRIMARY SEDIMENTATION
SETTLED SAMPLE
VACUUM FILTER
WASTE ACTIVATED SLUDGE
AERATION SYSTEM
LANDFILL
3
TREATED SAMPLE
EFFLUENT METER
4
EFFLUENT SAMPLE
TENNESSEE RIVER

Figure 6. Local Credits Sampling Diagram

remembered that this complicated program, which costs about 20% of the program budget, would not even be needed if Categorical Standards were not required in Chattanooga.

Funding - User Charges and Surcharges

Up to January 1, 1980, the pretreatment program was funded completely by user charges. However, the City Code has been amended to include surcharges, ICR (Industrial Cost Recovery) and other specific charges as required in the Construction Grant Regulations (40 CFR Part 35). The principal source of new revenue will be from high-strength surcharges; this revenue is estimated at over one-half million dollars, (about 20% of the O and M budget for 1980). This will pay for increased operation and maintenance costs to treat excess BOD_5, COD, and Suspended Solids. The increased costs also include the costs of the pretreatment program as shown in Table 8. Some industries questioned surcharging for both BOD_5 and COD. In actuality the BOD_5 and COD charges were calculated separately and do not constitute double charging. An industry with a relatively compatible waste would not notice the difference in its bill if the rate structure had been set up for BOD_5 alone. However, an industry discharging a waste with a high COD to BOD_5 ratio, or an otherwise incompatible waste will pay more because of the difficulty of treating that type waste. An interim rate structure is shown in Table 9 which was developed by the POTW staff. A final rate structure is being developed under an EPA contract by the City's consultant engineers.

Federal Pretreatment Program

The previously described activities of ordinance revision and sampling programs were further complicated by the uncertainties associated with the requirements of Section 307 (b) and (c) of PL 92-500 and the Clean Water Act Amendments. The 40 CFR Part 403 General Pretreatment Regulations, which implement Section 307, were first proposed in February 1977, barely a month after the passage of the first comprehensive ordinance. As stated earlier, doubts were cast upon the usefulness and applicability of the 1977 ordinance by several groups with a vested interest in its contents.

The City agreed that the ordinance should be revised but felt that the most prudent course to follow would be to wait until Part 403 was promulgated in its final form. The 18-month delay until the final rule was published proved to be an agonizing period of frustration which strained the patience and credibility of all participants in the local program development. During this period, the City was actively gathering data to support needed limitation revisions as described earlier.

The administrative requirements and content of the 403 local programs closely paralleled, and added to the requirements of the Step II Grant conditions for Chattanooga discussed earlier. Most of the tasks required for an approved 403 pretreatment program, particularly the development of the sewer ordinance, has already been undertaken in order for the City to comply with the special grant agreements.

TABLE 7. SUMMARY OF LOCAL CREDITS SAMPLING AS OF DECEMBER 1979

Toxic Parameter	Number of One Week Sampling Period*	Number of Data Point **	Overall Average % Removal ***	403.7 % Removal July 78/Oct. 79 +	403.7 % Removal Latest 4 Quarters
Antimony ++	5	31	31.5	--	--
Arsenic ++	5	30	--	--	--
Cadmium	6	41	54.1	34.6	29.1
Chromium	5	35	55.8	31.7	24.9
Copper	6	42	70.7	54.6	46.5
Cyanide ++	6	16	--	--	--
Lead	6	42	66.7	53.2	49.6
Mercury ++	5	24	--	--	--
Nickel	6	42	40.2	18	14.9
Phenol	6	25	61.8	35.8	20.9
Selenium +++	5	--	--	--	--
Silver	5	34	60.1	35.5	39.2
Zinc	6	42	62.8	43.6	50.0

* Sampling was performed for one seven-day week per calendar quarter.

** Number of valid data points as determined by 40 CFR 403.7; some were discarded because they were below the limit of detection; also not all parameters were measured for 7 days.

***Arithmetic mean of percent removal between sampling point #2 and #3.

+ Criteria as proposed on October 29, 1979.

++ Averages showed a "negative" removal possibly due to digester recycle having a 21-day detention time which is greater than the seven-day monitoring period.

+++All Selenium concentrations were below the limit of detection.

TABLE 8. PROJECTED ANNUAL PRETREATMENT PROGRAM COSTS (1980)

Activity	Lab Analysis	Sampling	Equipment	Administration	Total
Industrial Sampling and Compliance Monitoring (183 permits checked avg. 2 days/year)	$42,441	$18,985	$6,578	$16,100	$84,104
Local Credits Sampling in-plant (7 days/quarter at 4 plant locations)	$12,988	$ 7,448	$ 767	$12,100	$33,303
Quality Control	$ 5,543	--	$ 330	$ 3,400	$ 9,273
Permit Writing, Appeals, Compliance Checking, Data Processing, Typing, Misc., Administration	--	--	$4,392	$32,400	$36,792
TOTAL	$60,972	$26,433	$12,067	$64,000	$163,472

TYPING GUIDE SHEET
EPA-287 (Cin.)
(4-76)

Additional tasks required by Part 403 and included in the 1978 ordinance were:

1) Development of procedures to notify industrial contributors of their responsibilities and to notify them of applicable local and National Pretreatment Standards. Although not required of the City prior to EPA program approval, the POTW staff has been promulgated or proposed. This type service has helped to enhance the rapport between the City and the industrial dischargers and is relatively simple to accomplish by using a computer program to sort for SIC Codes.

2) Compliance with public participation requirements in the enforcement of National Standards to include annual public notice of industial users not in compliance with the program.

TABLE 9. SCHEDULE OF INTERIM SEWER RATES

Meter Rates	Uniform O & M User Charge	Service Charge	Total
For the first 50,000 gal.	$0.181	$1.028	$1.209
For the next 50,000 gal.	$0.181	$0.885	$1.066
For the next 100,000 gal.	$0.181	$0.751	$0.932
For the next 250,000 gal.	$0.181	$0.761	$0.942
For the next 300,000 gal.	$0.181	$0.618	$0.799
For the next 500,000 gal.	$0.181	$0.565	$0.746
For the next 750,000 gal.	$0.181	$0.508	$0.689
For all over 1,000,000 gal.	$0.181	$0.490	$0.671
For all over 3,000,000 gal.	$0.181	$0.293	$0.474

SURCHARGE RATES

Pounds of BOD over 300 mg/l	$0.0105124
Pounds of COD over 600 mg/l	$0.0066148
Pounds of Suspended Solids over 400 mg/l	$0.0143145

The ordinance controls originally required by the grant have been structured to have the legal authority to implement the formal pretreatment program called for by the regulation. In many cases this was accomplished by incorporating the language from the Federal Register directly into the ordinance.

A major flaw in the current 1978 ordinance is the lack of any significant civil or criminal penalty for violators as required in Section 403.8. In Tennessee, local governments do not have the authority to require a fine greater than $50.00 for each ordinance violation. When the city makes formal application for program approval, it will rely on a provision of Tennessee law authorizing the imposition of higher civil penalties at the State level as evidence of preemption. Additionally, the City attorneys have discussed this problem with State representatives and believe that, since the Tennessee legislature has traditionally been slow to act in the environmental area, that EPA pressure will be needed to achieve immediate results. If this cannot be accomplished, the attorneys believe that all of the local governments required to develop pretreatment programs in the State could successfully petition the Tennessee legislature for relief (4).

Enforcement of Chattanooga Ordinance Standards against industrial users outside the City limits is another significant problem since sewer discharges are received from across city, county, and state lines. So far, no users outside the City have challenged the legal validity of these permits. This is attributed to basic acceptance by industry of the importance of discharge control, and the fairness and reliability of the current ordinance standards. However, the City is working on developing contracts with the affected industries to cover this deficiency.

Other municipalities required to tie onto the Chattanooga system as part of the area-wide 208 plan will sign contracts which include a commitment to adopt the essential elements of the Chattanooga City Code. The POTW staff feels that eventually the system will be converted into a district with the power to pass its own ordinances. This approach will be much less cumbersome than the present system.

National Pretreatment Costs

The EPA estimated monitoring costs for municipalities and industries, as reported in the supplementary information preceeding the final regulation, were inadequate and misleading. The EPA estimated total cost (adjusted for the Moccasin Bend Plant being larger than the "average" plant of 16-33 MGD) for the 1979-1983 period was $143,451. This represented the net local share of the costs estimated by EPA after federal funding. Based on experience in the City of Chattanooga, the monitoring costs alone for one year will be more than the EPA adjusted estimate for 5 years of implementing the 403 requirements. The actual cost to the City for the initial sampling was $161,854 for 70 discharges from 45 of the largest industries. By today's guidelines on construction grants from EPA, this type of end-of-pipe sampling is being discouraged, however, the POTW staff feels that it could not have dealt with the enormous magnitude of the pretreatment problem in Chattanooga without the high confidence level stemming from data gathered in the City's sampling program.

The industrial community will also be hit hard. One consultant estimated that industrial monitoring costs in Chattanooga will be about $780,000 per year or about $6,000 annually per industry to accomplish the minimum sampling required by the City ordinance and permits. Table 10 shows that for the Electroplating Standards, the analysis costs alone will triple without concurrent increased environmental or administrative benefits.

Problems with National Categorical Standards

EPA miscalculated the cost of compliance with Part 403 by a factor of 13 with their estimated cost of $460 per year per industry. For this reason the City feels that the EPA needs to make a very thorough analysis of the environmental benefits versus the cost of adding the National Categorical Standards to a program which already is likely to cost much more than its proposed price tag. EPA did not attempt to estimate the cost to industry of actual compliance with the National Categorical Standards in Part 403. The City staff can appreciate the fact that estimating this cost before publication of the categorical standards was a difficult task. However, this represents a significant hidden cost of the overall pretreatment program. It would have been interesting to see the results of an Economic Impact Statement if EPA had been required to evaluate the full national cost of the pretreatment program and strategy. A study by the State of Tennessee (5) estimated that the $100 million mark was greatly exceeded (which would have made an Economic Impact Statement mandatory).

The present inflexible, cumbersome, costly, and difficult program of the National Pretreatment Strategy was not defined by Congress. However, the basis of its patch work of consent decrees, court decisions, and informal agreements between EPA and environmental groups is nonetheless rooted in the vague wording of Section 306 and 307 of the Act. The main thrust of this Strategy was determined primarily by Court action. Cities and POTW authorities generally had little input into this strategy because of the lack of technical knowledge and money at that time. The strategy direction largely came from environmental activist groups who don't have to run the programs or pay for them. Ironically, municipalities which are the keystones in this program and are the most logical enforcement agencies were not made an integral part of the decision making process.

The major argument used by EPA to support the national standards is "Parity." However, this argument fails in practice, since water quality standards take precedence (properly so) for many direct dischargers who may otherwise be regulated by a less stringent national standard. Thus, the primary concern for direct dischargers is really with controlling the pollutant load to the stream. This is also the most logical approach. Since parity is actually invalid, then it is unreasonable to force indirect dischargers to meet standards based on this concept. This is most significant in those cases where there are good local programs which are structured to meet the intent of the Act, and that control the pollutant load to the stream, which is the basic objective in the first place.

TABLE 10. ANNUAL INCREASE IN INDUSTRIAL SELF - MONITORING ANALYSIS COSTS DUE TO EPA NATIONAL STANDARDS FOR ELECTROPLATERS

Industry Flow gpd	Existing Permit $ Analysis	Permit w/National Standards, $ Analysis*	Difference $	New Compliance Requirements
250,000	972	5,076	4,104	none
149,000	5,148	26,354	21,106	Zn,CN,Cu,total metals
47,240	294	1,658	1,364	none
5,180	358	879	521	none
3,315	150	671	521	none
1,000	52	580	528	none
600	2,819	3,223	404	none
TOTAL	$9,793	$38,441	$28,648	

*Based on Commercial Lab Rates

As the National Standards are being proposed, the same inequities reported by Patterson (6) are again being repeated. A brief comparison in Table 11 between the Electroplating Standards and the Textile Standards for Chromium, Copper and Zinc (while not as extreme as the "thousand fold" difference for Arsenic reported by Patterson) nonetheless reflect a difference in discharge standards for the same pollutant that is unrelated to treatment technology. These differences are also apparent between standards for dischargers of the same type but of different sizes, as in the Electroplating Standard. Whatever happened to "parity" here?

Proposing fundamental changes to the Pretreatment Strategy to EPA has been, and will be fruitless because the Agency is bound by the above described network of suits and decisions, and its own bureaucratic inertia. The only avenue of change, then, is through Congressional action to clarify and redefine the Act and the National Strategy in light of the lessons learned in the initial stages of the Pretreatment Program. To achieve this end, Chattanooga has approached its Congressional delegation and received a favorable response, and encourages other municipalities to do likewise. The first goal of this action is to obtain a moratorium on the compliance dates for the National Standards until municipal local programs are functioning. Those programs that demonstrate that the main goals of plant and environmental protection in Section 307 of the Clean Water Act can be achieved by local standards should be incorporated into those POTW's NPDES permits in such a manner to allow those cities the authority to operate independently of the National Categorical Standards. Such independent operation should be licensed only so long as the POTW control authority continues to meet its NPDES permit requirements and sludge criteria.

This approach should provide a positive driving force to encourage municipalities to develop local programs and to operate their POTW's as efficiently as possible. It will also focus attention on insuring that NPDES permits are comprehensive enough to include standards that are directly related to water quality protection. Publication of proposed water quality criteria in 1979 (7) for the 65 toxics makes this goal realistic. Finally, these changes should help to dispel the reluctance of State and local agencies to take on the program as it is presently structured, and to provide those agencies with positive incentives to convert the national goals into viable programs.

TABLE 11. COMPARISON OF PROPOSED TEXTILE PRETREATMENT STANDARDS WITH THE FINAL ELECTROPLATING PRETREATMENT STANDARDS

		Textile Mills		Electroplating	
Industrial Flows	Pollutant	Daily (mg/l)	30 day (mg/l)	Daily (mg/l)	30 day (mg/l)
Greater Than 10,000 gpd	Chromium	0.9	0.5	7.0	2.5
	Copper	0.9	0.5	4.5	1.8
	Zinc	1.8	1.0	4.2	1.8
Less Than 10,000 gpd	Chromium	0.9	0.5	no limits	
	Copper	0.9	0.5	no limits	
	Zinc	1.8	1.0	no limits	

REFERENCES

1. Federal Guidelines; State and Local Pretreatment Programs. EPA-430/9-76-017a, U.S. Environmental Protection Agency, Washington, D.C., 1977, p. 179.

2. Dietz, J.C., and Dietz, J.D. A Rationale for Pretreatment Standards for Industrial Discharges to Publicly Owned Treatment Works. In: Proceedings of the 33rd Industrial Waste Conference, Purdue University, Indiana, 1978. pp. 121-127.

3. Denit, J. EPA's Forty Plant POTW Toxic Survey. In: Proceedings of the National Pretreatment Symposium, AMSA, Duluth, Minnesota, 1979. pp. 102-116.

4. AMSA. Pretreatment Program Implementation: Can It Really Be Done? Washington, D.C., 1979.

5. O'Dette, R.G., and Kurz, G.E. The State of Tennessee Pretreatment Position Paper. Nashville, Tennessee, 1977.

6. Patterson, J.W. Technical Inequities in Effluent Limitations Guidelines. Journal Water Pollution Control. 49(7): 1586-1590, 1977.

7. EPA. Water Quality Criteria. In: Federal Register, Washington, D.C., 1979. pp. 15926-15981, 43660-43697, 56628-52629.

PB83-142323

INVESTIGATIONS ON THE SUITABILITY OF VARIOUS PESTICIDE MANUFACTURING WASTEWATER FOR DISCHARGE TO MUNICIPAL WASTE TREATMENT FACILITIES

E. C. Monnig*
TRW
Environmental Engineering Division
Research Triangle Park, N. C. 27709

L. W. Little
L.W. Little Associates
P. O. Box 10035
Raleigh, N. C. 27605

R. Zweidinger
Research Triangle Institute
Research Triangle Park, N. C. 27709

ABSTRACT

The biological treatment of wastewaters from the production of atrazine, carbaryl, dazomet, dinoseb, glyphosate, maneb, mancozeb, and oryzalin is discussed. Data are presented indicating that the mechanism of removal during biological treatment of volatile organics such as toluene probably involves significant volatilization. Data are presented on the use of activated carbon as a pretreatment to biological treatment. A final example is noted regarding the difference between ozonating a pesticide in a pure solution and a pesticide in a mixed wastewater.

INTRODUCTION

The pesticide industry includes the manufacture of approximately 300 active ingredients at 139 manufacturing sites across the country (Kelso, 1978). The total U.S. production of pesticides amounted to 1.4 billion pounds in 1974 (Kelso, 1978). The industry is highly diversified. In 1974, 205 of the active ingredients were manufactured by single producers, though this trend is changing as the patent rights on several important products expire.

Discharges from pesticide manufacturing sites are regulated under section 301, 304, 306, and 307 of P.L. 92-500 (Federal Water Pollution

---

*Research conducted at Research Triangle Institute and supported by EPA contracts 68-02-2612 and 68-02-3688.

Control Act Amendments or the "Clean Water Act"). The focus of concern in these discharges has been on three areas: traditional parameters including BOD, COD, TSS, and pH; the 129 so called "consent decree priority pollutants"; and the pesticide concentrations.

Regulations promulgated thus far in conjunction with Best Practical Treatment (BPT) standards reflect in large measure the current state of information on methods for treating the parameters of interest and methods for analyzing the efficiency of treatment methods for pesticide manufacturing wastewater.

Based on availability of treatment methods and analysis methods, the pesticide industry was broken into several groups during the promulgation of BPT standards. A group of pesticides or pesticide classes was excluded from all regulation (see Table 1). A second group of 49 pesticides was regulated for BOD, COD, TSS, pH, and pesticide concentration (see Table 2). All other pesticides not listed in the first two categories were regulated with reference to BOD, COD, TSS, and pH except that organometallics were assigned a no-discharge status.

Given the need for methods of treatment and analysis of pesticide wastewaters, several EPA research laboratories have been actively supporting research in these areas. This report highlights research supported by the Industrial Environmental Research Lab, RTP-NC as it related to treatment of pesticide manufacturing wastes in municipal waste treatment systems.

BIOLOGICAL TREATMENT

The studies were designed in part to investigate the ability of a municipal waste treatment system, as modelled by bench-scale activated sludge units, to treat various pesticide manufacturing wastes. The efficiency of treatment was determined by measuring traditional parameters such as COD, ammonia, solids levels, as well as pesticide concentration and break-down products before and after treatment. Toxicity of wastes before and after treatment was monitored by algal assays (Selenatrum capricornutum) and with daphnia or fathead minnows.

The bench-scale unit used in these studies is described by Swisher (1970) and is shown in Figure 1. The treatment efficiency of this smaller units was found to give very similar results to a larger unit (4-5 liters) developed by the Organization of Economic Cooperation and Development (OECD) for studies on biodegradation of surfactants. This larger unit is depicted in Figure 2.

All the studies have involved actual pesticide manufacturing wastes which were collected at the manufacturing facility prior to any treatment. The samples were all collected from single manufacturing process waste-streams. The pesticides wastewaters investigated thus far have included atrazine, carbaryl, dazomet, dinoseb, glyphosate, maneb, mancozeb, MSMA, and oryzalin. It would not be possible here to give complete details on each of these studies. Several reports have been or will be published on these studies and are listed in the bibliography; however, general and

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE
6-1/2"
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

Table 1 Pesticides and Classes of Pesticides Excluded from BPT Regulations

Allethrin
Benzyl benzoate
Bilphenyl
Bisethylxanthogen
Cholorophacinone
Coumafuryl
Dimethyl phthalate
Diphacinone
Endothall acid
EXD (Herbisan)
Gibberellic Acid
Glyphosate
Methoprene

Naphthalene acetic acid
Phenylphenol
Piperonyl butoxide
Propargite
1,8 Naphthalic anhydride
Quinomethionate
Resmethrin
Rotenone
Sulfoxide
Sodium phenylphate
Triazine compounds (both symmetrical and asymmetrical)
Warfarin and similar anticoagulants

TABLE 2. PESTICIDES REGULATED FOR BOD, COD, TSS, pH AND PESTICIDE CONCENTRATION

Aldrin
Aminocarb
Azinphos methyl
Barban
BHC
Captan
Carbaryl
Chlordane
Chlorpropham
2,4-D
DDD
DDE
DDT
Demeton-O
Demeton-S
Diazinon
Dicamba
Dichloran
Dicofol
Dieldrin
Disulfoton
Diuron
Endosulfan
Endurin
Fenuron
Fenuron-TCA
Heptachlor
Lindane
Linuron
Malathion
Methiocarb
Methoxychlor
Mexacarbate
Mirex
Monuron
Monuron-TCA
Neburon
Parathion ethyl
Parathion Methyl
PCNB
Perthane
Propham
Propoxur
Siduron
Silvex
SWEP
2,4,5,-T
Trifluralin
Toxaphene

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE

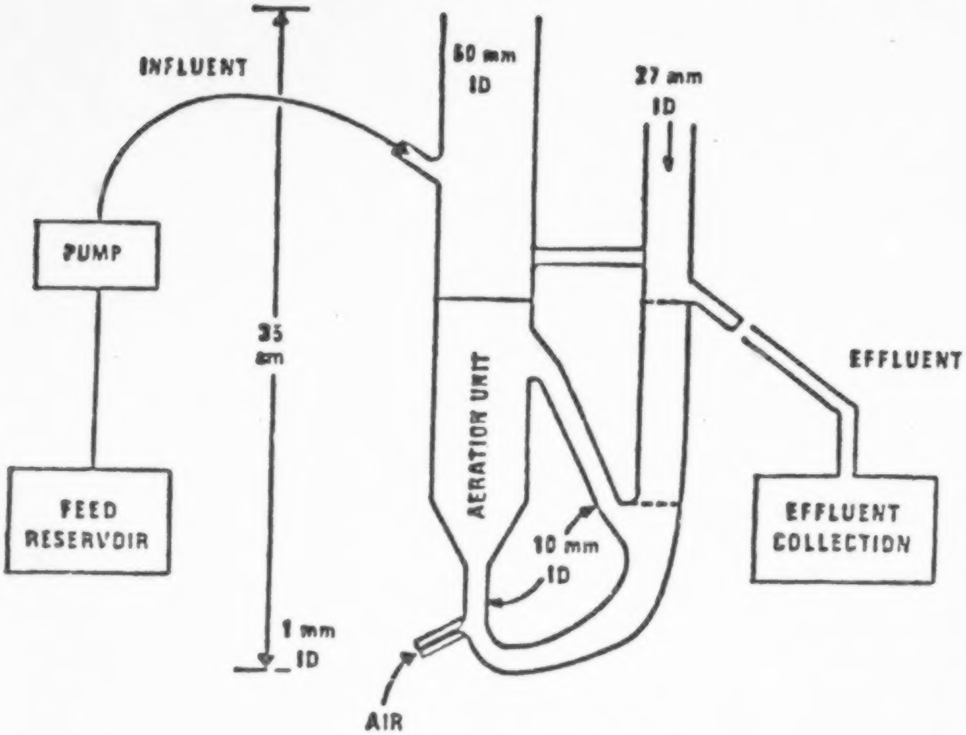

INFLUENT
60 mm ID
27 mm ID
PUMP
35 cm
AERATION UNIT
EFFLUENT
FEED RESERVOIR
EFFLUENT COLLECTION
10 mm ID
1 mm ID
AIR

Figure 1. Diagram of Swisher Activated-Sludge Unit.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
1/2"
PAGE NUMBER
EPA-287 (Cin.) (4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE

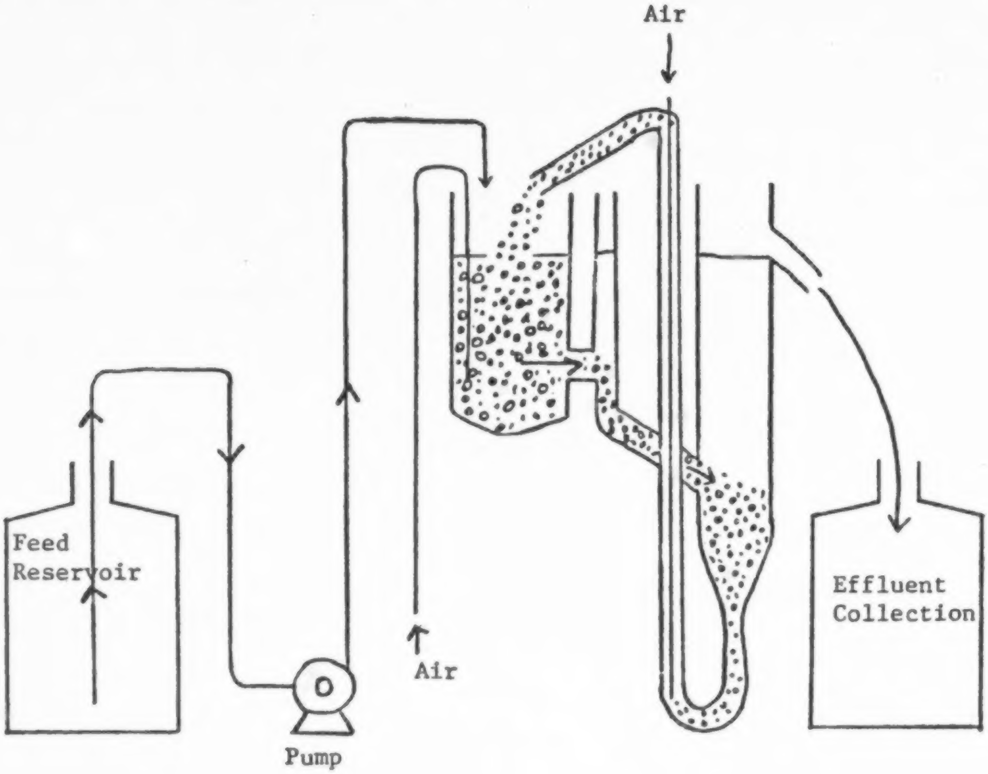

Air
Feed Reservoir
Pump
Air
Effluent Collection

Figure 2, Diagram of O.E.C.D. Activated Sludge Unit.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
PAGE NUMBER

summary statements can be made.

The pesticide concentration of the wastestreams from the manufacture of carbaryl, maneb, mancozeb, and dazomet could be degraded within the constraints of a municipal treatment system. Dilution factors ranged from 0.1 to 10 percent in municipal wastewater. In addition, the associated organics in these wastewaters and the municipal wastewater were also readily degraded as measured by the COD test.

It is interesting to note that the half-lives of these pesticides in the soil range from 6 hours to 60 days depending of conditions. Qualitative predictions of the effect of biological treatment can sometimes be made based on data on the fate of these pesticides in the soil. Data relative the fate of a pesticide in the soil are now typically compiled during the registration procedure and can be accessed through EPA's Office of Pesticide Programs or through the manufacturer if they are not in the open literature.

Two herbicides were relatively unaffected by biological treatment yet did not seem to interfere with biological processes. Glyphosate, at concentrations from 25 to 100 mg/L, was only partial removed during biological treatment (40% removal). However, COD of the wastewaters was reduced as much as 89% during biological treatment. Atrazine concentrations from 1 to 60 mg/L showed only partial removal during biological treatment (20%). However, the atrazine wastewater did not seem to interfere with the biological treatment of municipal wastewater.

The dinoseb and oryzalin wastewaters were both highly concentrated with COD's as high as 14,500 and 45,000 mg/L, respectively. Both wastes had high dissolved solids, 280,000 mg/L and 73,000 mg/L, respectively. Both wastes showed a high tendency to disrupt biological treatment even at dilutions as low as 1 ml/L in municipal wastewater.

Even in cases where municipal biological treatment of pesticides wastewaters seems feasible, several provisos should be noted. The ethylene-bis-dithiocarbamate pesticides such as maneb and mancozeb produce ethylene thiourea as a breakdown product which is a suspected thryoid carcinogen. Dazomet produces methylisothiocyanate as a breakdown product. While both ethylene thiourea and methylisothiocyanate are relatively short lived in soil and water (half lives on the order of days), they have potential effects that should be monitored.

Apparent interference with nitrification processes was also noted in the treatment of mancozen, dazomet, and carbaryl wastewaters. The dazomet concentrations were reduced >95% at dilutions of 1 part dazomet wastewater to 100 parts municipal wastewater. However, at dilutions of 1 to 1000 in municipal wastewater, the dazomet wastewater reduced nitrification by as much as 50%. This effect is probably due to the presence of methyl-isothio-cyanate which has been shown to inhibit nitrification by 75% at concentrations as low as 0.8 mg/L. (Tomlinson, 1966). Similar patterns were exhibited for maneb-mancozem and carbaryl wastes, depending on concentration.

Many of the pesticide wastes studied contained substantial quantities of volatile organic compounds including acetone, toluene, and formaldehyde. The fate of these compounds in biological treatment systems has been the subject of some question. Based on results obtained during our studies it would appear that during biological treatment volatile organic compounds of low water solubility may be removed primarily through air stripping rather than biological degradation.

Where appropriate, a air-stripping control was run during our studies. The industrial waste was mixed at the appropriate dilution with distilled water instead of municipal wastewater. The mixture is then pumped through a biological treatment unit which contains distilled water instead sludge. COD and the appropriate compounds are analyzed in the influent and effluent. Table 3 includes data on toluene concentration in carbaryl wastewater before and after air stripping. Mere exposure of a sample of diluted wastewater (10% in DIW) to open air for 24 hours reduced toluene levels from 16 mg/L to 0.9 mg/L. Pumping through the biological treatment unit further reduced concentration to 0.1 mg/L. More water-soluble compounds such as formaldehyde and acetone show a less consistent pattern. Additional research will be required to determine these mechanisms of removal.

CARBON PRETREATMENT

Given the relatively refractory nature of most pesticides, removal of this component before discharge to a POTW will probably be required. One possible method for pretreatment is the use of activated carbon as a selective filter. Because most pesticides are relatively high-molecule weight compounds with low water solubility, they may be adsorbed preferentially onto activated carbon relative to more water-soluble organics. The use of this technique was demonstrated with a combination of dinoseb and atrazine wastes.

The waste in question contained effluent from an atrazine process (30 mg/L atrazine) which was contaminated with some washwater from a dinoseb manufacturing process (5 mg/L dinoseb). This wastewater was treated in a carbon column 2.5 cm in diameter which was filled to a height of 45 cm with a slurry of 100 grams (dry weight) of carbon. The bed volume of this column was 221 mL. Dinoseb-atrazine composite waste (pH unadjusted) was pumped through this column at a rate of 13 mL/min (0.63 $gal/ft^2/min$).

A total of 105 bed volumes (23.2 L) was pumped through the column. No dinoseb or atrazine was detected at any point in the effluent from the carbon column. The rise in COD levels with increasing bed volumes followed a sigmoid pattern as presented in Figure 3. The COD of bed volumes 81-105 was approzimately that of the untreated sample. In a full scale version of this system, the carbon which has been expended in treating the dilute dinozeb-atrazine waste is then used to treat the concentrated dinoseb wastestream referred to above. Because the quantity of a dinoseb sorbed to carbon is a function of the concentration in solution, very high loadings are achieved. This carbon treatment can reduce dinoseb from 800 mg/L to less than 20 mg/L in the concentrated dinoseb waste. COD can be reduced as much as 75% depending on the breakthrough volume used. Since this

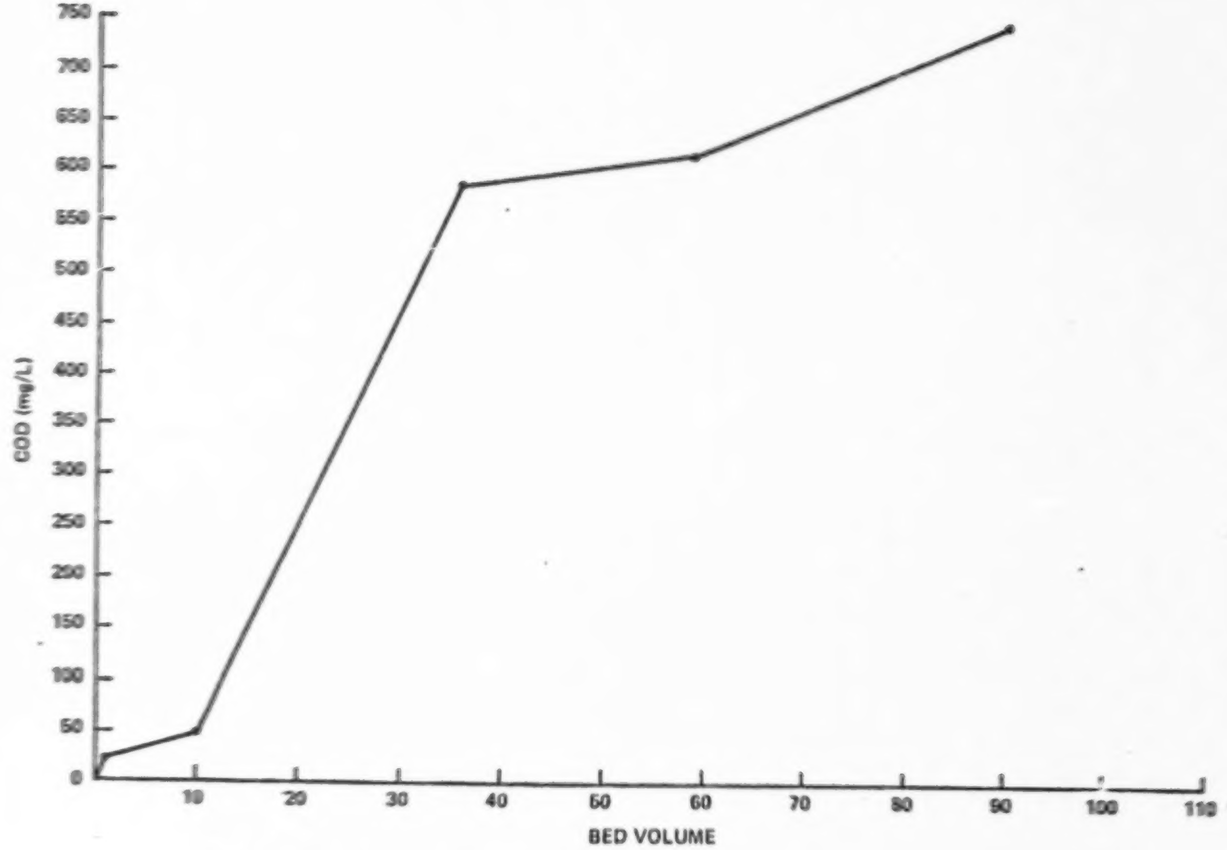


Figure 3. Chemical oxygen demand of various fractions of carbon treated dinoseb-atrazine composite.

TABLE 3. TOLUENE CONCENTRATIONS IN VARIOUS FRACTIONS OF CARBARYL WASTEWATER

Sample	Toluene Concentration (mg/L)
Carbaryl waste undiluted	160
Biological treatment units (10% carbaryl waste in municipal waste)	
Influent after 24 hours	2.5
Effluent	0.001
Air stripping control units (10% carbaryl waste in deionized water)	
Influent after 24 hours	0.9
Effluent	0.1

concentrated wastestream is a relatively small fraction of the total plant effluent, it can then be combined with the dilute dinoseb-atrazine stream and retreated with clean carbon. The organics that breakthrough this final carbon can then be biologically treated.

OZONATION

A final example demonstrates the difference between treating a compound in a pure solution and treating the same compound in a real-world wastestream. Figure 4 presents data on the rate of ozonation of glyphosate in distilled water. Ozone was supplied at a rate of 42 mg/minute. In the presence of an excess concentration of ozone, destruction of glyphosate followed first-order kinetics with respect to glyphosate concentration. The time constant for the reaction, as computed from the slope of -0.0095, was 0.219 min^{-1}. The half life of glyphosate under these conditions was about 32 minutes.

By contrast the ozonation of glyphosate production wastewater after initial biological treatment produced little reduction in glyphosate concentration. The ozonation of a biologically treated effluent containing 92 mg/L glyphosate and 400 mg/L COD was attempted. Two hours of ozonation at the same rate as above reduced glyphosate concentration by only 12 mg/L.

SUMMARY

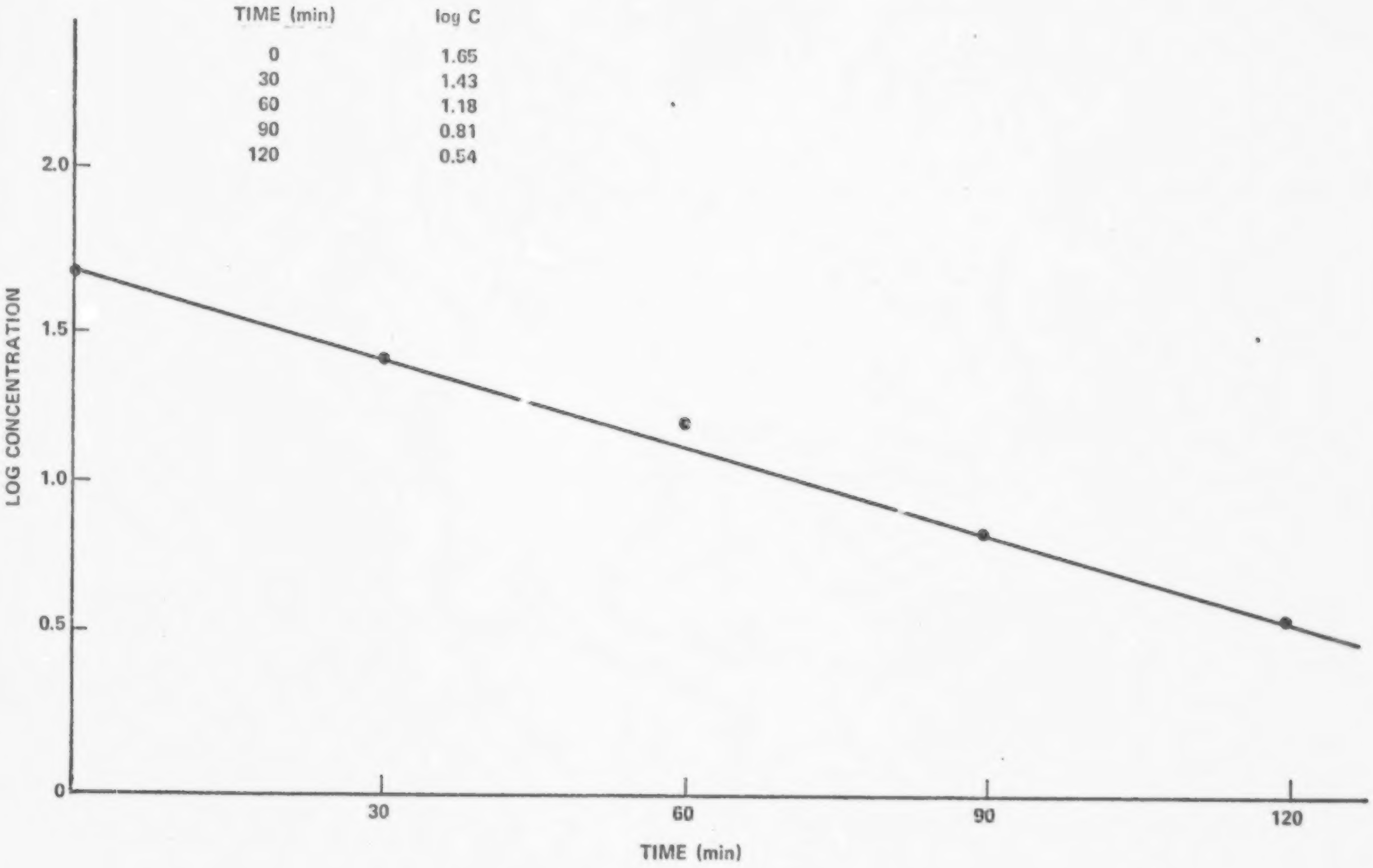
The increasingly strict standards governing the discharge of pesticide production wastewaters may reduce the number of such wastestreams which are currently discharged to POTW's. The BPT pesticide standard for those wastestreams regulated is 0.0018 pounds of pesticide discharged after the final treatment step for every 1000 pounds of pesticide produced. Achieving this standard after municipal treatment would require extensive pretreatment of most pesticide wastewater. Given the cost of pretreatment, many manufacturers may find it cheaper to design a complete treatment system including a biological system tailored to their specific needs.

REFERENCES

Kelso, G. L., R. R. Wilkinson, J. R. Malone, Jr., and T. L. Ferguson. Development of Information on Pesticides Manufacturing for Source Assessment. EPA-600/2-78-100, Environmental Protection Agency, Research Triangle Park, N. C., 1978.

Swisher, R. D. Surfactant Biodegradation. Marcel Dekker, Inc. N. Y., 1970.

Tomlinson, T. G., A. G. Boon, and C. N. Trotman. Inhibition of Nitrification in the Activated Sludge Process of Sewage Disposal. Jour. Appl. Bact. 29(2) 266-291, 1966.



TIME (min)	log C
0	1.65
30	1.43
60	1.18
90	0.81
120	0.54

Figure 4. Rate of ozonation of glyphosate.

BIBLIOGRAPHY

Little, L. W., R. Zweidinger, E. Monnig, and W. J. Firth. *Treatment Technology for Pesticide Manufacturing Effluents: Atrazine, Maneb, MSMA, Oryzalin*. EPA-600/2-80-043, EPA, RTP, NC, 1980.

Monnig, E. C., R. Zweidinger. *Treatment Technology for Pesticide Manufacturing Effluents: Carbaryl*. Final Report for Contract 68-02-3688. EPA, IERL, RTP, NC (in press).

Monnig, E. C., R. Zweidinger. *Treatment Technology for Pesticide Manufacturing Effluents: Dinoseb and Atrazine*. Final Report for Contract 68-02-3688, EPA, IERL, RTP, NC (in press).

Monnig, E. C., R. Zweidinger. *Treatment Technology for Pesticide Manufacturing Effluents: Dazonet*. Final Report for Contract 68-02-3688, EPA, IERL, RTP, NC (in press).

Monnig, E. C., R. Zweidinger, M. Warner, R. Batten, D. Liverman. *Treatment Technology for Pesticide Manufacturing Effluents: Glyphosate*. Final Report for Contract 68-02-3688, EPA, IERL, RTP, NC (in press).

Zweidinger, R., T. Wolff, R. Hendren, R. Batten, M. Warner, D. Liverman, L. Little. *Treatment Technology for Pesticide Manufacturing Effluents: Mancozeb*. Final Report for Contract 68-02-3688, EPA, IERL, RTP, NC (in press).

PB83-142331

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD, BEGIN SECTIONS HERE

LOS ANGELES COUNTY EXPERIENCE IN THE CONTROL AND TREATMENT OF INDUSTRIAL WASTEWATER DISCHARGES

By: L. S. Directo, Supervising Civil Engineer
C. W. Carry, Asst. Chief Engineer and Asst. General Manager, and
J. F. Kremer, Head, Industrial Waste Section
County Sanitation Districts of Los Angeles County
1955 Workman Mill Road
Whittier, California 90607

ABSTRACT

The Sanitation Districts of Los Angeles County (LACSD) adopted, on April 1, 1972, an ordinance regulating industrial wastewater discharges. This ordinance established a number of industrial waste regulatory programs which included industrial waste permits, an industrial surcharge program, industrial plant inspections, and wastewater monitoring and enforcement activities. The basic element of the industrial waste source control program is the implementation of the Phase I industrial wastewater effluent limits, which have been strictly enforced since July 1, 1977. The effluent guidelines established discharge limits for cyanide, heavy metals and total identifiable chlorinated hydrocarbons (TICH). This paper will discuss the impact of major industrial companies on the Districts' Joint Outfall System (JOS) sewerage system and wastewater treatment facilities and the role of the Districts in the implementation and enforcement of the Phase I limits. The effectiveness of the source control program in the JOS will also be discussed by examining the influent pollutant mass flows to the Districts' Joint Water Pollution Control Plant (JWPCP). For instance, examination of the mass inflow data to JWPCP from January 1975 to December 1979 reveals significant decreases in the levels of As, Cr, Cu, Cn, Pb, Zn and TICH, but only minor decreases for such parameters, as Ag, Cd, Hg and Ni. It is estimated that approximately 85% of the affected industrial companies are now meeting the Districts' Phase I limits through good housekeeping techniques.

INTRODUCTION

The Sanitation Districts of Los Angeles County (LACSD), which were created in the 1920's under the authority granted by the California County Sanitation Districts Act of 1923, provide sewerage facilities for treatment and disposal of sanitary and industrial wastewaters generated from areas largely within the Los Angeles County boundary. There are currently 27

BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
BEGIN LAST LINE OF TEXT
3/8
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE

separate sanitation districts comprising the LACSD. Fifteen of these districts have combined to form the Joint Outfall System (JOS), which provide a common sewerage system serving approximately 3.7 million people and 8000 industrial companies located in 74 cities encompassing about 750 square miles of Los Angeles County. The Sanitation Districts' JOS has five inland treatment plants providing secondary and tertiary treatment facilities with a combined capacity of about 80 mgd. The sixth and largest treatment plant in the JOS, the Joint Water Pollution Control Plant (JWPCP), provides advanced primary treatment and deep ocean disposal for 350 mgd of wastewater. Figure 1 presents the service area of the JOS. The JWPCP is currently being converted to partial secondary treatment with a scheduled completion for 200 mgd capacity by 1982.

The main objective of this paper is to describe the LACSD experience in the administration and implementation of a rigorous source control program in an effort to control and/or minimize adverse effects of industrial wastewaters on the sewerage system and wastewater treatment facilities.

ESTABLISHMENT OF AN INDUSTRIAL WASTE SOURCE CONTROL PROGRAM

Before 1972, the Sanitation Districts did not have a strong program of controlling industrial wastewater discharges. Because of its organizational structure, the Sanitation Districts do not control local sewers, hence had no information on requests for industrial sewer connections. The industrial waste source control program available at that time consisted of:

a) Districts' policy restricting discharges to the Districts' trunk sewers. This policy required local cities to submit to the Districts certain information on any proposed industrial sewer connection.

b) Prohibitions of industrial wastewater discharges containing cyanide, flammable materials, low pH or constituents which would clog the sewers. Enforcement of these specific prohibitions were accomplished either through the local cities or through the powers granted to the Districts under state laws.

These earlier source control programs, while adequate in the 1960's, could not meet more stringent regulations established in 1972 by Federal Public Law 92-500 and in the State of Califnornia Original Ocean Plan. Thus, to meet both Federal and State water quality goals, the Sanitation Districts adopted, on April 1, 1972, "An Ordinance Regulating Sewer Construction, Sewer Use and Industrial Wastewater Discharges" (Ordinance). The Ordinance has been established to adequately regulate industrial wastewater discharges, to provide for equitable distribution of the Districts' costs through a user charge (surcharge) program and to provide procedures for complying with the requirements imposed upon the Districts by Federal and State agencies.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

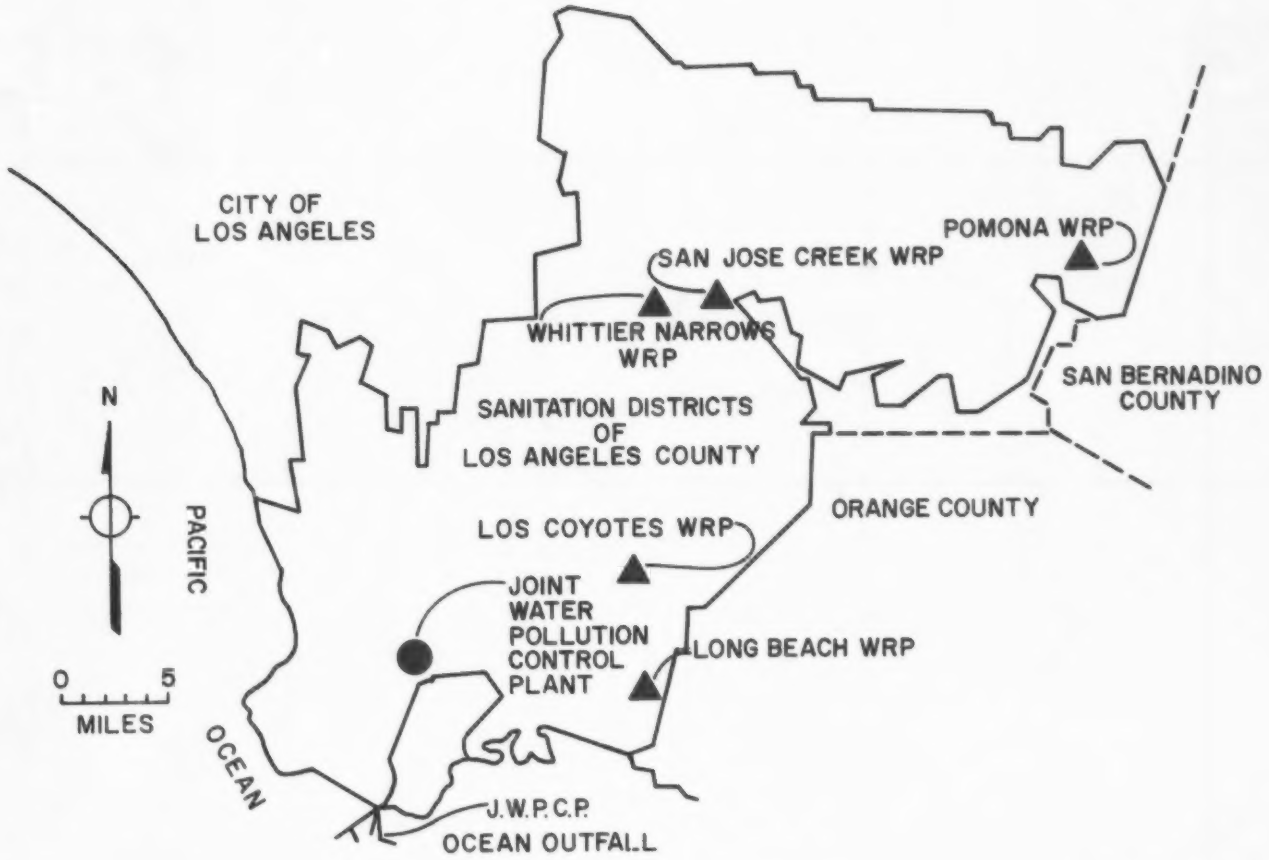

CITY OF LOS ANGELES
SAN JOSE CREEK WRP
POMONA WRP
WHITTIER NARROWS WRP
SAN BERNADINO COUNTY
SANITATION DISTRICTS OF LOS ANGELES COUNTY
ORANGE COUNTY
LOS COYOTES WRP
JOINT WATER POLLUTION CONTROL PLANT
LONG BEACH WRP
J.W.P.C.P. OCEAN OUTFALL
PACIFIC
OCEAN
N
0
5
MILES

Figure I. Joint outfall districts

EPA-287 (Cin.)
(4-76)

The Districts' Ordinance, which became effective on July 1, 1972, mandated the establishment of an industrial wastewater discharge permit program to identify and regulate industrial dischargers. As part of the permit program, all existing and new industrial companies are required, as a prerequisite to obtaining an industrial wastewater discharge permit, to submit information indicating the volume, composition and concentration of the wastewater discharge and describing the industrial process and wastewater pretreatment facility. The permit program, which requires certain industrial dischargers to submit periodic self-monitoring reports on specified wastewater parameters, provides the basic information used in establishing numerical effluent limits for source control of toxic wastewater constituents. No major source control efforts were, however, made until after July 1, 1975.

ADMINISTRATION OF THE INDUSTRIAL WASTE PROGRAM

Personnel Requirements

Figure 2 presents the organizational structure of the Industrial Waste Section. This section is charged with the responsibility of implementing the Districts' industrial waste regulatory program. There are currently 48 positions filled out of the 66 persons authorized for the Section. Among the 48 positions, 16 are graduate engineers (4 Ph.D., 7 M. S. and 5 B. S. degree graduates), 14 industrial waste inspectors, 6 monitoring crew persons, 5 surcharge auditors, 2 drafting technicians and 5 clerical support people. The Section is composed of 4 subsections which are under the direct supervision of the Section Head. The main functions of these subsections are described below.

Permit Processing Subsection

In accordance with Section 401 of the Districts' Ordinance, all companies discharging industrial waste directly or indirectly to the Districts' sewerage system are required to apply for an industrial wastewater discharge permit for each sewer connection. All new industrial companies must obtain a permit before their wastewater can be accepted in the Districts' sewerage and treatment facilities. Under this permit program, industrial dischargers are required to (a) submit detailed information on their wastewater generating operation, (b) install necessary pretreatment facilities to meet Districts' requirements, and (c) periodically report wastewater flow and wastewater characterization test data.

The main function of this subsection is to implement the Districts' industrial wastewater discharge permit program. All permit applications submitted by industrial companies are reviewed by the plan evaluation engineers or the drafting technicians to insure that adequate information on the process generating the wastewater is provided and that complete information on spill containment, flow monitoring and pretreatment facilities is provided. Review of permit applications from existing industrial companies locates and identifies industrial wastewater problems which can be corrected through permit requirements. Permit requirements placed on new construction submittals prevent potential problems from occurring.

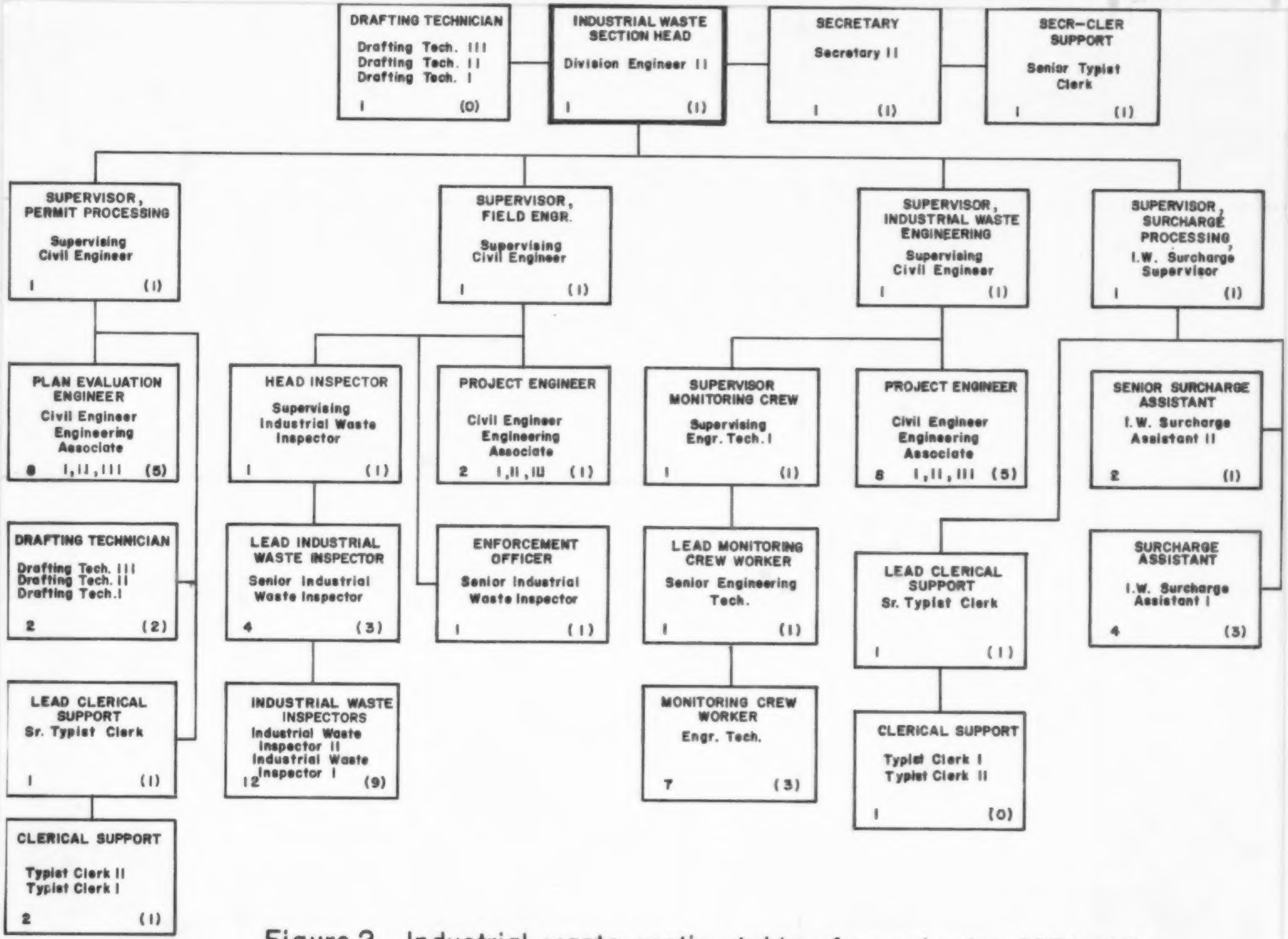

DRAFTING TECHNICIAN
Drafting Tech. III
Drafting Tech. II
Drafting Tech. I
1 (0)
INDUSTRIAL WASTE SECTION HEAD
Division Engineer II
1 (1)
SECRETARY
Secretary II
1 (1)
SECR–CLER SUPPORT
Senior Typist Clerk
1 (1)
SUPERVISOR, PERMIT PROCESSING
Supervising Civil Engineer
1 (1)
SUPERVISOR, FIELD ENGR.
Supervising Civil Engineer
1 (1)
SUPERVISOR, INDUSTRIAL WASTE ENGINEERING
Supervising Civil Engineer
1 (1)
SUPERVISOR, SURCHARGE PROCESSING,
I.W. Surcharge Supervisor
1 (1)
PLAN EVALUATION ENGINEER
Civil Engineer
Engineering Associate
8 I,II,III (5)
HEAD INSPECTOR
Supervising Industrial Waste Inspector
1 (1)
PROJECT ENGINEER
Civil Engineer
Engineering Associate
2 I,II,III (1)
SUPERVISOR MONITORING CREW
Supervising Engr. Tech. I
1 (1)
PROJECT ENGINEER
Civil Engineer
Engineering Associate
8 I,II,III (5)
SENIOR SURCHARGE ASSISTANT
I.W. Surcharge Assistant II
2 (1)
DRAFTING TECHNICIAN
Drafting Tech. III
Drafting Tech. II
Drafting Tech. I
2 (2)
LEAD INDUSTRIAL WASTE INSPECTOR
Senior Industrial Waste Inspector
4 (3)
ENFORCEMENT OFFICER
Senior Industrial Waste Inspector
1 (1)
LEAD MONITORING CREW WORKER
Senior Engineering Tech.
1 (1)
LEAD CLERICAL SUPPORT
Sr. Typist Clerk
1 (1)
SURCHARGE ASSISTANT
I.W. Surcharge Assistant I
4 (3)
LEAD CLERICAL SUPPORT
Sr. Typist Clerk
1 (1)
INDUSTRIAL WASTE INSPECTORS
Industrial Waste Inspector II
Industrial Waste Inspector I
12 (9)
MONITORING CREW WORKER
Engr. Tech.
7 (3)
CLERICAL SUPPORT
Typist Clerk I
Typist Clerk II
1 (0)
CLERICAL SUPPORT
Typist Clerk II
Typist Clerk I
2 (1)

Figure 2. Industrial waste section table of organization, 1979–80

Inspection and Monitoring Subsection

This subsection is responsible for carrying out the industrial wastewater source inspection and monitoring programs, to insure that the Districts' regulatory program is properly observed and that adequate control measures are practiced by industrial dischargers. This subsection also carries out treatment plant upset investigations, and where appropriate, will carry out enforcement actions against industrial wastewater dischargers who are in non-compliance with the Districts' Ordinance requirements. The inspection function is carried out by 12 inspectors operating in 3 teams under the supervision of one supervising inspector.

The industrial waste monitoring program, which is carried out by 5 monitoring crew members plus one supervisor, has been implemented to verify the flow rate and wastewater characterization test results reported via the industrial self-monitoring program. Approximately 350 major industrial wastewater dischargers (companies with wastewater flows equal to or greater than 50,000 gpd) are being monitored about twice a year. An additional 120 industrial wastewater dischargers are also being monitored about twice a year as part of the Phase I source control program. For the 1979 calendar year, about 2100 24-hour composite samples and/or flow measurements were made.

Industrial Wastewater Engineering Subsection

This subsection, which is made up of 6 project engineers (3 with PhD, and 3 with M.S. degrees) under one supervising civil engineer, provides technical support and expertise in specific industrial waste fields. The principal functions of the project engineers in this subsection are (a) to evaluate the activities of industrial companies with respect to wastewater quality and quantity, (b) to resolve technical and economic problems arising from industrial use of the Districts' sewerage system, (c) to provide a consulting service to the plan evaluation engineers in the permit subsection; reviewing major and critical permit applications, recommending appropriate permit conditions and developing technical and policy standards for use by the plan evaluation engineers, and (d) to assist personnel of the surcharge subsection in the development of technical information and guidelines needed in auditing industrial surcharge statement submittals.

The following are the major industrial waste fields with an assigned industrial waste project engineer:

(a) Petroleum Product and Refining
(b) Metal Finishing
(c) Chemical Process
(d) Food and Beverage Processing
(e) Paper and Textile Manufacturing
(f) Basic Metals

Surcharge Processing Subsection

This subsection has the responsibility of administering the Districts' industrial wastewater treatment surcharge program, in effect since July 1, 1972, for the following purposes:

(a) To insure that industrial dischargers using the Districts' sewerage system pay an equitable share of the treatment costs,

(b) To comply with revenue programs promulgated by State and Federal agencies, and

(c) To provide economic incentives to the industrial companies to control pollutants at the source.

In the seven years since the surcharge program has been in effect, the Districts have collected a total of 36.58 million dollars from industrial companies. For the fiscal year 1978-1979, a total of 7.3 million dollars net surcharge was collected from 1,151 companies.

Cost of Administering the Industrial Waste Program

The total expenses from the administration and implementation of the Districts' industrial wastewater source control program were $1.27 million during the 1978-1979 fiscal year. It is anticipated that the cost of administering the industrial waste regulatory program may increase in subsequent years because of increased levels of regulatory activities required to implement more stringent Federal pretreatment regulations.

IMPLEMENTATION OF THE INDUSTRIAL WASTEWATER SOURCE CONTROL PROGRAM

In 1975, the Sanitation Districts established a source control program geared to meet the following major objectives:

(a) To allow the JWPCP and the five other inland water reclamation plants within the JOS to comply with the effluent discharge limitations established by the 1972 California Ocean Plan.

(b) To protect the public, the environment and Districts' personnel and facilities from potentially harmful industrial wastewater discharges.

(c) To maintain a reasonable cost-benefit ratio for Districts' services to the public.

The basis for implementing the districts' source control program is the Phase I limits, shown in Table I. These limits were adopted for the JOS by the Sanitation Districts' Board of Directors on July 1, 1975. The limits shown in Table 1 were developed in cooperation with the Metal Finishing Association of Southern California, the City of Los Angeles, and the Sanitation Districts of Orange County. It should be pointed out that the Phase I limits were developed to comply with the orginal California Ocean Plan effluent limits, presented in Table 2, which were established on July 6, 1972.

As the first step in the implementation of the Districts' source control program, copies of Phase I limits along with detailed definitions

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE

TABLE 1. INDUSTRIAL WASTEWATER EFFLUENT LIMITATIONS*

Constituent	Industrial Wastewater Effluent Limitations Phase I Control Period (mg/l)
Arsenic	3
Cadmium	15
Chromium (Total)	10
Copper+	15
Lead	40
Mercury	2
Nickel	12
Silver	5
Zinc	25
Cyanide (Total)	10
Total Identifiable Chlorinated Hydrocarbons	Essentially None

* Adopted on July 1, 1975 for Joint Outfall Districts.

+ Based on toxicity criteria rather than the Ocean Plan Limits.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA. OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TABLE 2. CALIFORNIA OCEAN PLAN EFFLUENT LIMITATIONS*

Constituent	Effluent Limitations (mg/l)
Arsenic	0.01
Cadmium	0.02
Total Chromium	0.005
Copper	0.2
Lead	0.1
Mercury	0.001
Nickel	0.1
Silver	0.02
Zinc	0.3
Cyanide	0.1
Phenolic Compounds	0.5
Total Chlorine Residual	1.0
Ammonia	40.
Grease and Oil (hexane extractables)	10.
Total Identifiable Chlorinated Hydrocarbons	0.002

* Water Quality Control Plan for Ocean Waters of California, established July, 1972.

and guidelines for meeting the requirements, were mailed to about 700 affected companies, mainly metal finishing companies, in October 1975. In these mass mailings, the Districts established an 18-month compliance period to provide companies ample opportunity to institute a Phase I source control program capable of meeting the effluent limits. An additional 6-month extension was added by the Districts to the original compliance date. Thus, it was not until July 1, 1977 when the Phase I limits began to be rigorously enforced.

During the 24-month interim period prior to the enforcement of the Phase I limits, the Sanitation Districts embarked on a comprehensive program designed to identify industrial companies which would require controls on their wastewater discharges. The program was carried out through the following steps:

(a) A list of industrial companies, especially those with Standard Classification, (SIC) 3471 and 3479 for metal finishers, were compiled from the Districts' industrial wastewater discharge permit files and updated using information from telephone directories, manufacturers' registers and field inspection reports.

(b) The Districts' monitoring of industrial sources was established and a follow-up procedure was also initiated to improve industrial companies self-monitoring report submittals.

(c) All companies found in violation of the phase limits were notified by letter and required to submit information on a plan of action necessary to comply with established limits. The affected companies were also visited by Districts' inspectors to facilitate correction of existing problems.

Since July 1, 1977, industrial dischargers that show Phase I violations in their self-monitoring report submittals are sampled by the Districts' monitoring crews to confirm the indicated violation. Enforcement notices are issued to all industrial dischargers who are not in compliance as indicated in the test results of Districts' sampling.

ENFORCEMENT PROGRAM

While in general the majority of industrial dischargers have been in compliance with the Districts' Ordinance requirements, in a number of cases it has become necessary to initiate enforcement actions against recalcitrant companies. Enforcement actions are indicated in any one or more of the following:

(a) industrial discharges which cause treatment plant upsets
(b) delinquent surcharge problems
(c) violations of wastewater ordinance requirements

The present enforcement procedure is to issue non-compliance notices to companies, whenever a violation has been detected as a result of

Districts' inspection, sampling or testing. Three levels of notices are used in the enforcement process, issued in the following order:

(a) Information Notice
(b) Violation Notice
(c) Final Notice of Violation

After each notice is issued, the company is given a reasonable period of time, usually 30 days, to correct the non-compliance status. Failure to comply through these 3-step enforcement procedures may result in referring the matter to the District Attorney (D.A.) of Los Angeles County for consideration of criminal prosecution. To date, there have been only 12 cases that have gone beyond the third step of enforcement and only two cases were not resolved immediately soon after the D. A. conference. In both these cases, however, the offending company was found guilty in the court of law and compliance was quickly obtained. It should be emphasized that the Districts' policy in dealing with companies has been to foster cooperation and to give the non-complying company ample opportunity to correct the violation.

Table 3 presents a summary of the type and number of enforcement actions against industrial dischargers during 1979. The summary data indicate that the major percentage of enforcement activity was for Phase I limit violations. The enforcement activity from 1975 through December 1979 is presented in Figure 3. It is apparent from the figure that enforcement activities have increased appreciably after July 1, 1977 when Phase I limit enforcement was started. The greater number of enforcement actions in 1979 was brought about by a vigorous campaign to have companies comply with permit requirements to install flow monitoring, spill containment and rainwater diversion systems in addition to the installation of necessary pretreatment systems to comply with Phase I limits.

RESULTS OF THE DISTRICTS' SOURCE CONTROL PROGRAM

As discussed previously, the JOS serves a large portion of Los Angeles County and consists of the JWPCP and five inland water reclamation plants (WRP). These reclamation plants are operated so that all skimmings and sludges generated are discharged to an outfall sewer and eventually flow to the JWPCP. Since heavy metals and other pollutants removed from the five WRP are concentrated in the generated sludges which discharge to the JWPCP, the raw sewage data at the JWPCP are good indicators of the total mass pollutant flows in the JOS. Thus, the results of the Districts' source control program can best be presented by examining the long term trends of mass constituents in the flow to the JWPCP as shown in Figures 4 through 14. The results presented in these figures are 12-month running averages of the specific constituent. In each of these figures, the lower dotted band represents the estimated residential contribution; the solid line represents the original Ocean Plan discharge limits (the basis for the establishment of the Phase I limits); and the band of horizontal lines represents the estimated pollutant mass flow to the JWPCP when all companies are in full compliance with the Phase I limits.

TABLE 3. SUMMARY OF INDUSTRIAL WASTE ENFORCEMENT FOR 1979

Month	No. of Companies Under Enforcement	Total No. of Enforcement Actions	Type of Enforcement Action											
			Phase I		No Permit		Flowmeter		Low pH		Surcharge		Other	
			No.	% of Total	No.	% of Total	No.	% of Total	No.	% of Total	No.	% of Total	No.	% of Total
Jan.	57	60	36	60.1	1	1.7	11	18.3	4	6.7	0	0	8	13.3
Feb.	58	62	37	59.7	1	1.6	9	14.5	5	8.1	3	4.8	7	11.3
Mar.	67	75	44	58.7	3	4.0	7	9.3	10	13.3	3	4.0	8	10.7
Apr.	74	83	49	59.0	4	4.8	9	10.8	11	13.3	0	0	10	12.0
May	78	92	49	53.3	6	6.5	11	12.0	11	12.0	5	5.4	12	10.9
June	87	96	50	52.1	8	8.3	10	10.4	10	10.4	6	6.3	12	12.5
July	96	113	42	37.1	14	12.3	13	11.5	14	12.4	7	6.1	23	20.4
Aug.	104	104	33	31.7	30	28.8	19	18.2	12	11.5	1	0	9	8.6
Sept.	93	97	34	35.0	28	28.8	14	14.4	5	5.1	5	5.1	11	11.3
Oct.	89	94	28	29.8	20	21.2	21	22.3	6	6.4	8	8.5	11	11.7
Nov.	94	103	27	26.2	17	16.5	20	19.4	8	7.7	9	8.7	22	21.3
Dec.	94	104	27	26.0	13	12.5	23	22.1	6	5.8	10	9.6	25	24

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

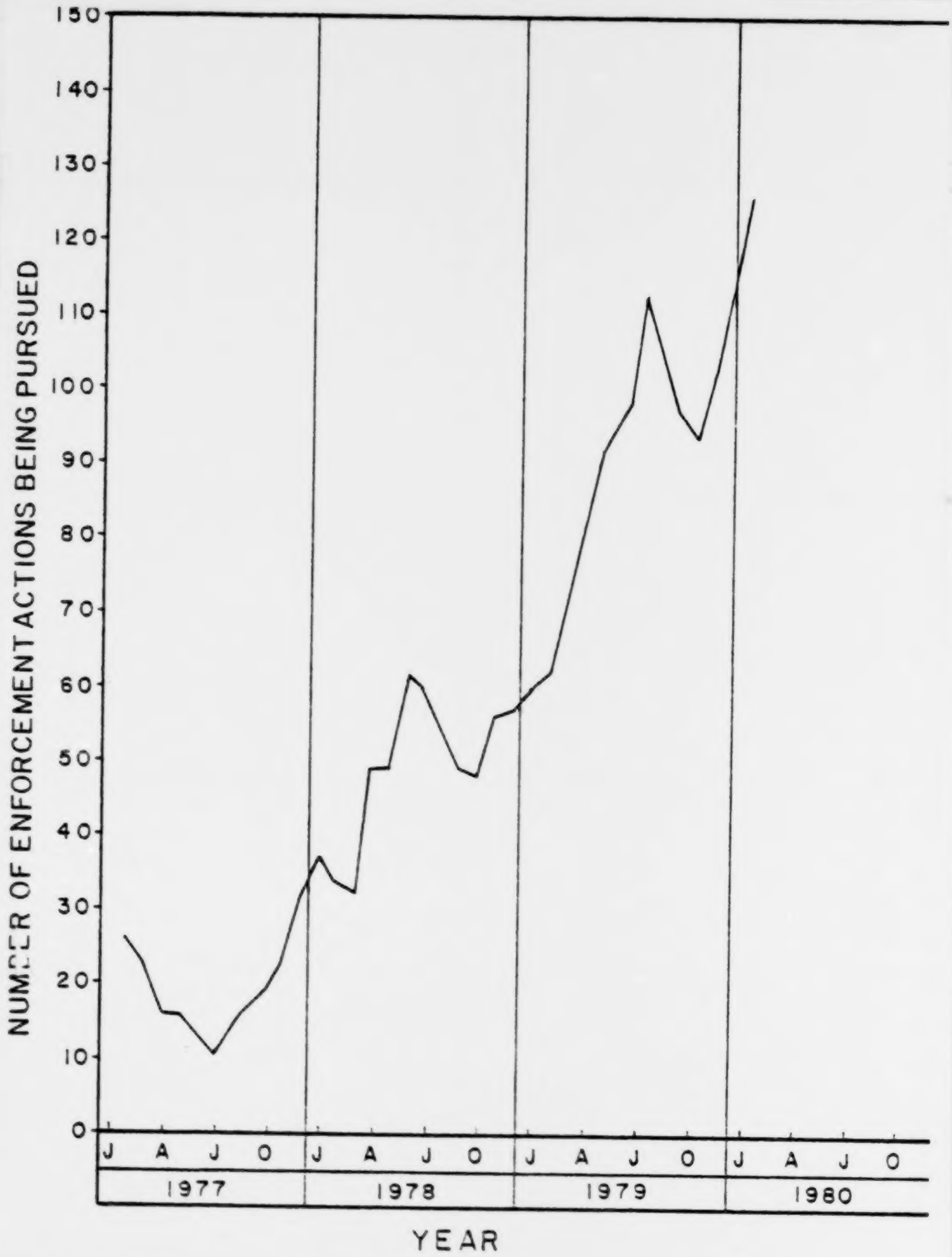


Figure 3. Summary of industrial waste enforcement activities

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
PAGE NUMBER

In examining the plots of the various constituents, it should be pointed out that prior to July 1975, when the Phase I limits were adopted, essentially no significant efforts were made by industrial companies to curtail toxic waste discharges. Therefore, the data points obtained in 1975 would provide a good estimate of the pre-source control baseline data.

Arsenic

Figure 4 presents the mass flow of arsenic. As indicated in the figure, the Districts have consistently met the Ocean Plan discharge limits since July 1975. While the source control program probably had a definite impact in the reduction of arsenic mass flow, it is believed that the following factors may also have contributed to the drop in arsenic: a) changes in the formulation of consumer products and b) improved laboratory analytical techniques. The current indicated average of 35 to 40 lbs/day is within the range expected if all companies are in full compliance with the Phase I limit of 3 mg/l.

Cyanide

The cyanide mass flow level in the JOS, presented in Figure 5 has consistently met the Ocean Plan discharge limit, even before the adoption of the source control program. Through vigorous efforts in implementing the source control program, many industrial companies have installed cyanide pretreatment equipment resulting in a 55% decrease in the cyanide mass flow at the JWPCP, to a current level of 540 lbs/day. This level of cyanide has been observed in the past two years, indicative of essentially full compliance of companies with the Phase I cyanide level of 10 mg/l.

As an accommodation to industrial companies, the Districts have been operating a cyanide disposal station at JWPCP. The toxic waste received at this station are bled at a controlled rate into a trunk sewer just upstream of JWPCP. Approximately 400 lbs/day of cyanide are currently being discharged at this station. This facility, however, will soon be closed because the EPA and the State of California regulations require compliance with certain pretreatment requirements for a hazardous disposal facility such as this. With an eventual closure of this facility, an additional cyanide reduction can be achieved for an overall removal of approximately 90% from the pre-source control baseline level.

Cadmium

As indicated in Figure 6, the cadmium levels through 1979 have been appreciably below the Ocean Plan discharge limits. From 1975 to date, the mass flow of about 85 to 100 lbs/day in the JWPCP influent is within the value expected with all companies in full compliance with the Phase I limit of 15 mg/l. The cyanide disposal station at JWPCP contributes approximately 10 lbs/day of cadmium; therefore, an additional reduction in cadmium is anticipated after the closure of the cyanide station.

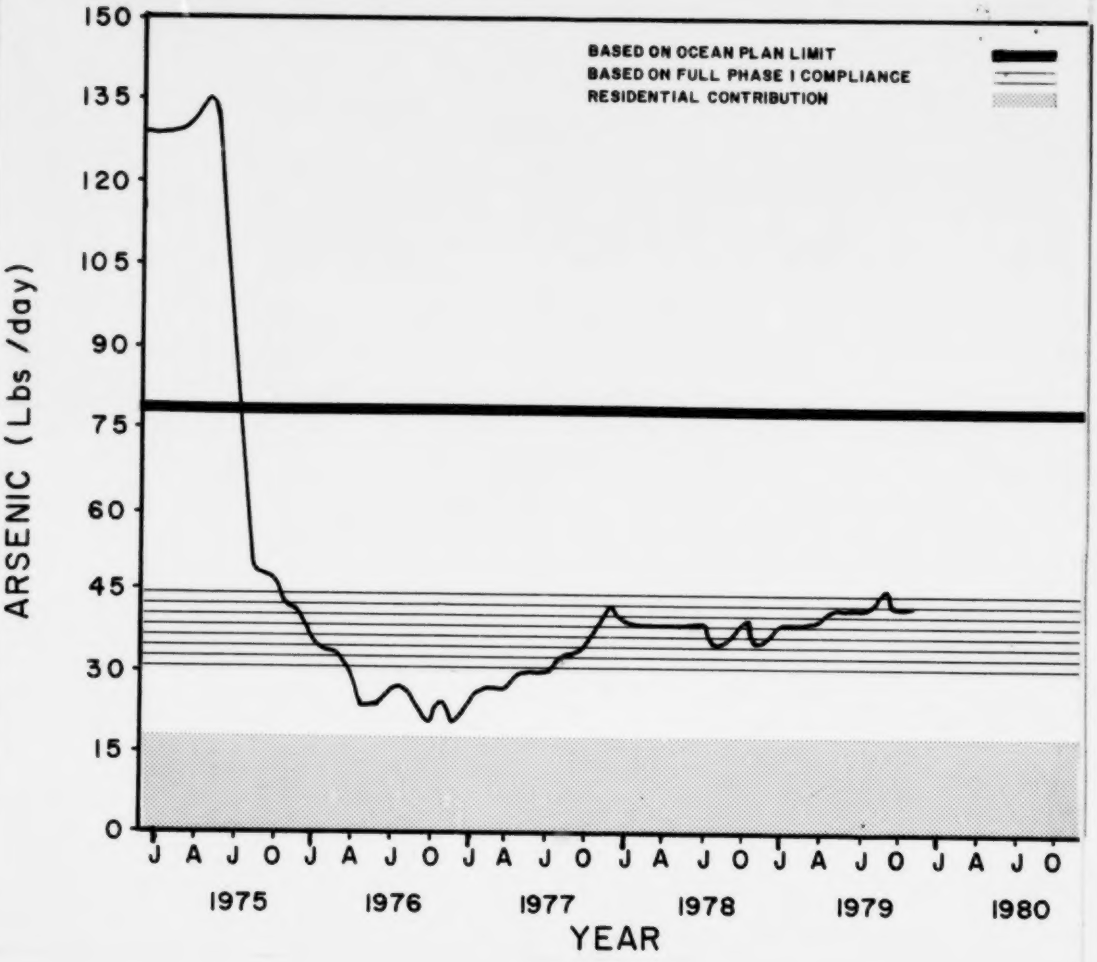


Figure 4. Mass inflow of Arsenic at the J.W.P.C.P.

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD, BEGIN SECTIONS HERE

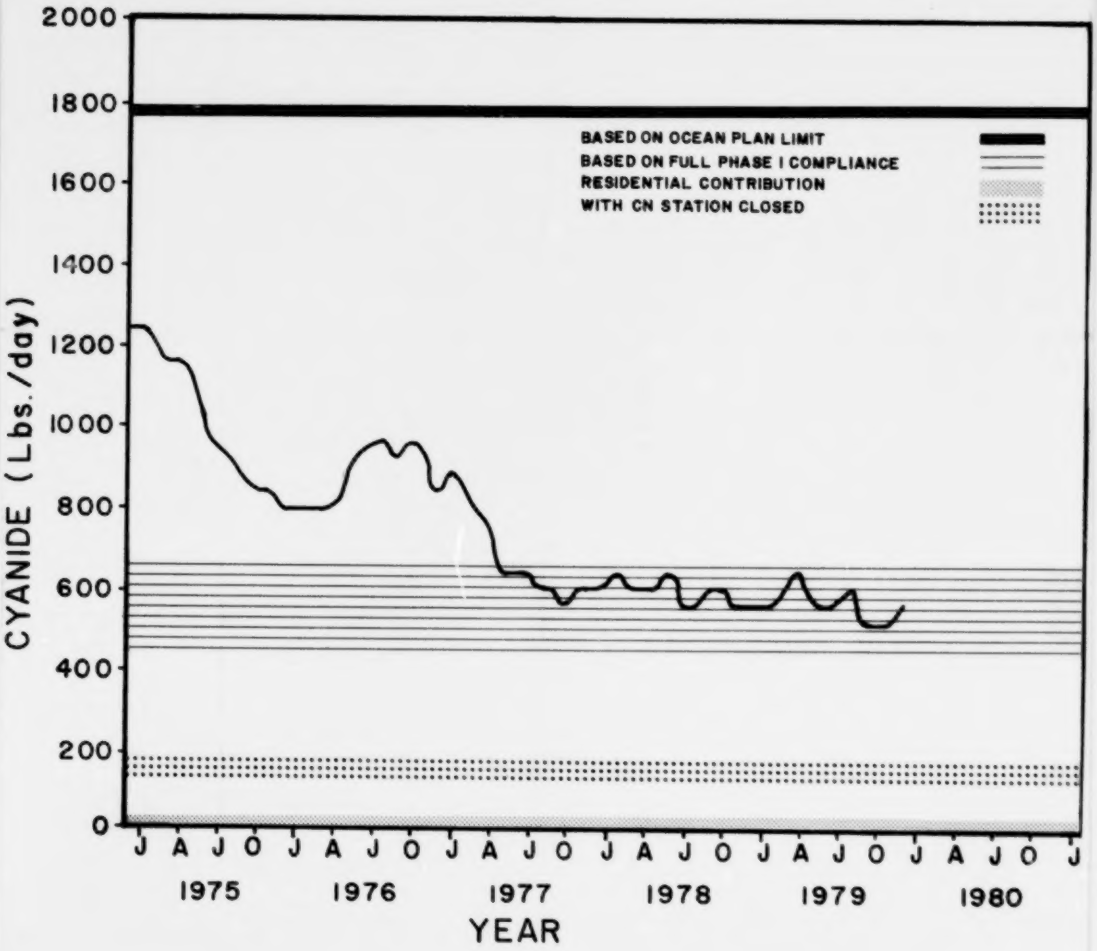


Figure 5. Mass inflow of Cyanide at the J.W.P.C.P.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8''

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

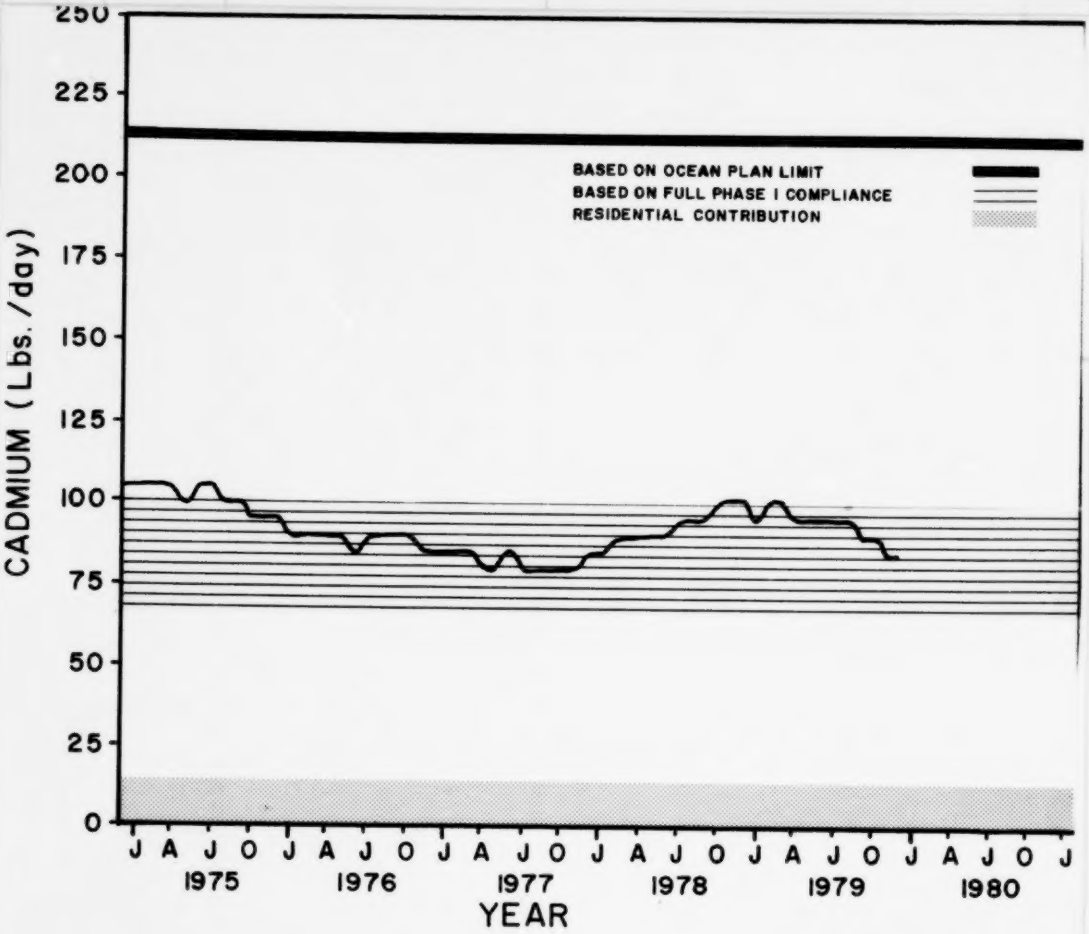


Figure 6. Mass inflow of Cadmium at the J.W.P.C.P.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

Chromium

As shown in Figure 7, there has been a dramatic decrease in the chromium levels at the JWPCP, starting about July 1976. This decrease of about 50% in the mass flow of chromium has been achieved as a result of vigorous enforcement of the Phase I limits. At the present time one large leather tanning company and a number of small plating companies are periodically in violation of the Phase I limits of 10 mg/l. It is evident from the figure, that even with full compliance by all companies with the Phase I limits the original Ocean Plan limit can never be met. With the current level of chromium at JWPCP, the districts should have no difficulty in meeting the 1978 revised Ocean Plan limit of 2,000 lbs/day.

Copper

The mass flow of copper presented in Figure 8 indicates a marked decrease of approximately 40% from the pre-source control level. The dash line at 1000 lbs/day copper is established on the basis of toxicity of copper to the activated sludge process and is more restrictive than the influent limit required by the Ocean Plan effluent limit. The Phase I source control program has been instrumental in this reduction in copper inflow. Although the copper concentration has consistently met the original Ocean Plan limit, it still is not within the range anticipated if all companies were to fully comply with the Phase I limits of 15 mg/l copper. An additional 80 lbs/day of copper is expected to be removed with the closure of the cyanide disposal station.

Lead

The decrease in the lead concentration in the JWPCP influent over the years is illustrated in Figure 9. As indicated in the figure, even before January 1975, the mass flow of lead has been continuously meeting the Ocean Plan limit. The source control program is believed responsible for approximately 20% of the lead removal at the JWPCP. Approximately an additional 10% should be removed with full compliance of industrial dischargers with the Phase I limit of 40 mg/l of lead.

Mercury

Ad indicated in Figure 10, there has been essentially no beneficial effect of the Phase I program on the control of mercury. It appears that mercury originates primarily from domestic sources, thus any control imposed on industrial dischargers will have virtually no effect on the mass inflow to JWPCP. The levels of mercury in the influent to JWPCP are within the range of concentration reported in EPA documents for structly sanitary wastewater.

Nickel

Figure 11 presents the mass inflow of nickel to the JWPCP. As indicated in this figure, the Phase I program has not had major success in reducing the level of nickel. Thus far, the nickel level has been above the

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

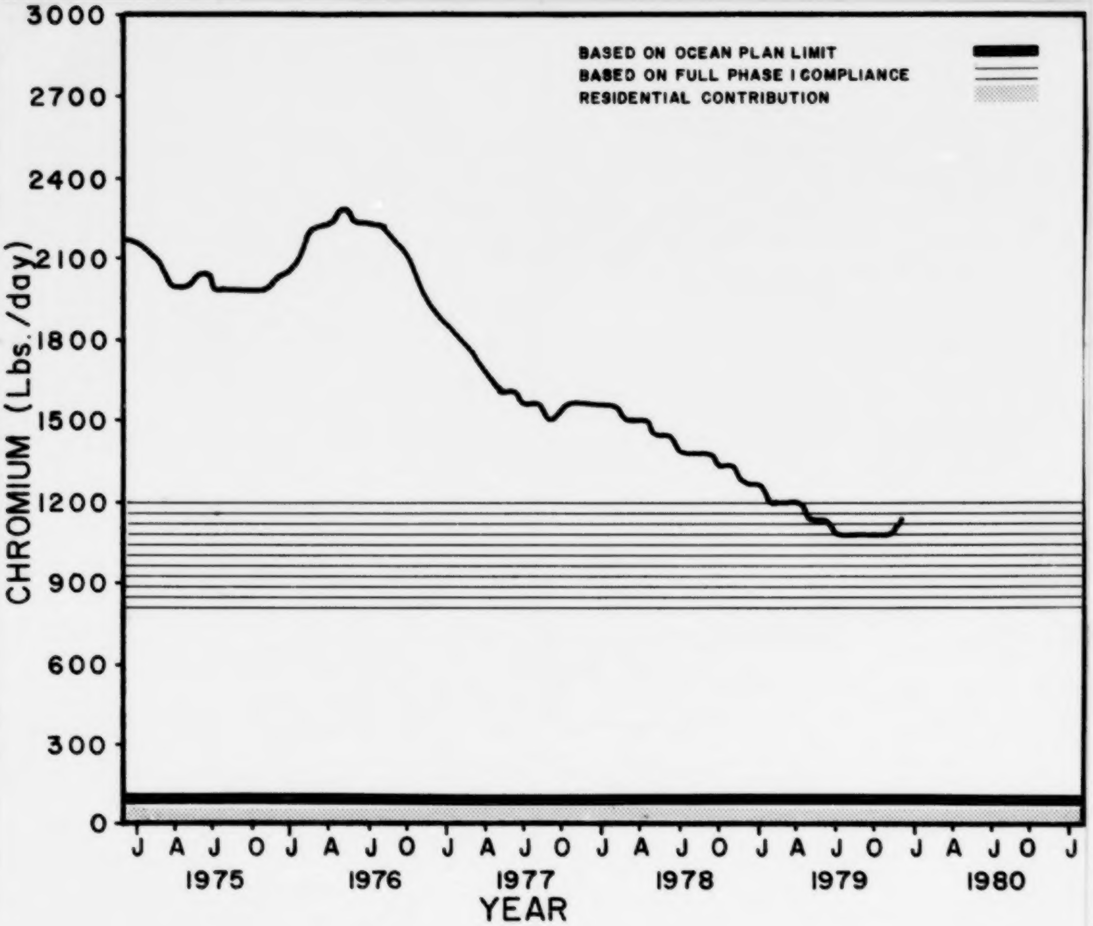


Figure 7. Mass inflow of Chromium at the J.W.P.C.P.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

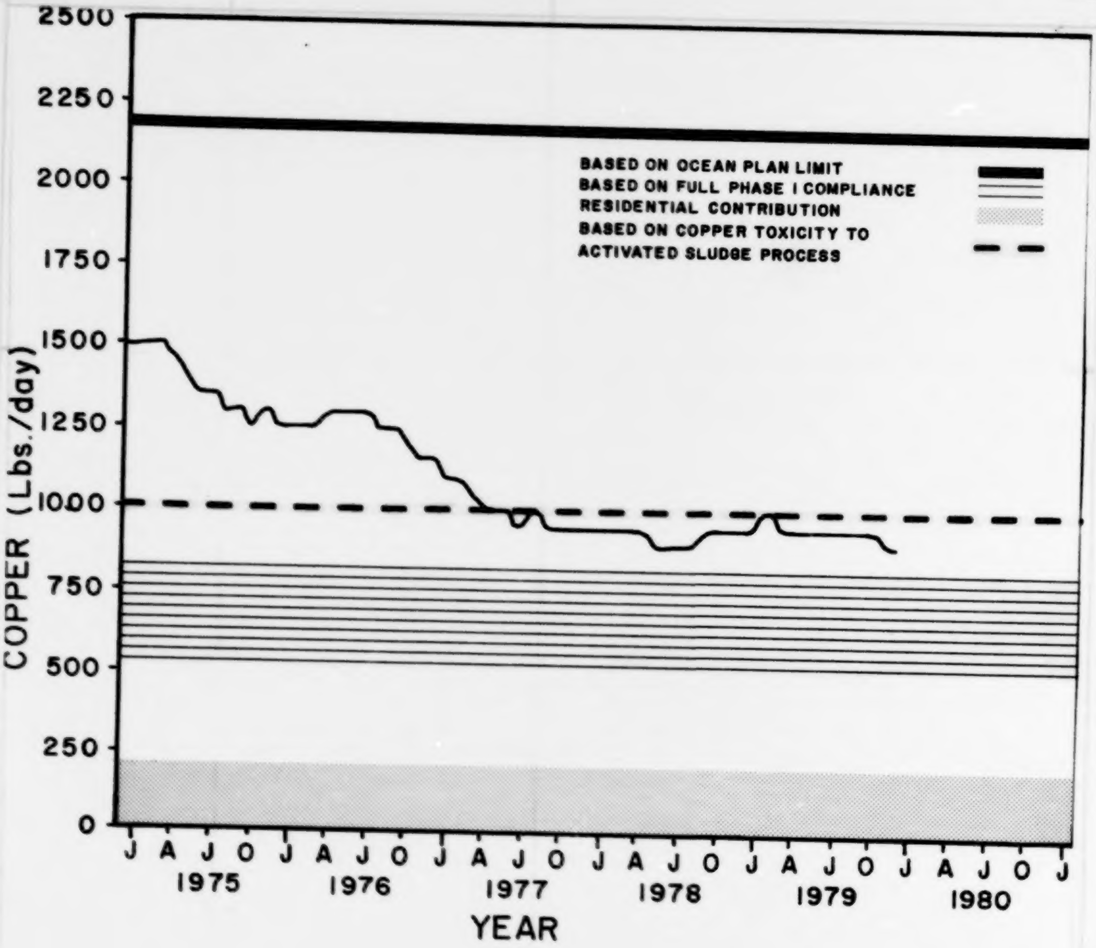


Figure 8. Mass inflow of Copper at the J.W.P.C.P.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD, BEGIN SECTIONS HERE

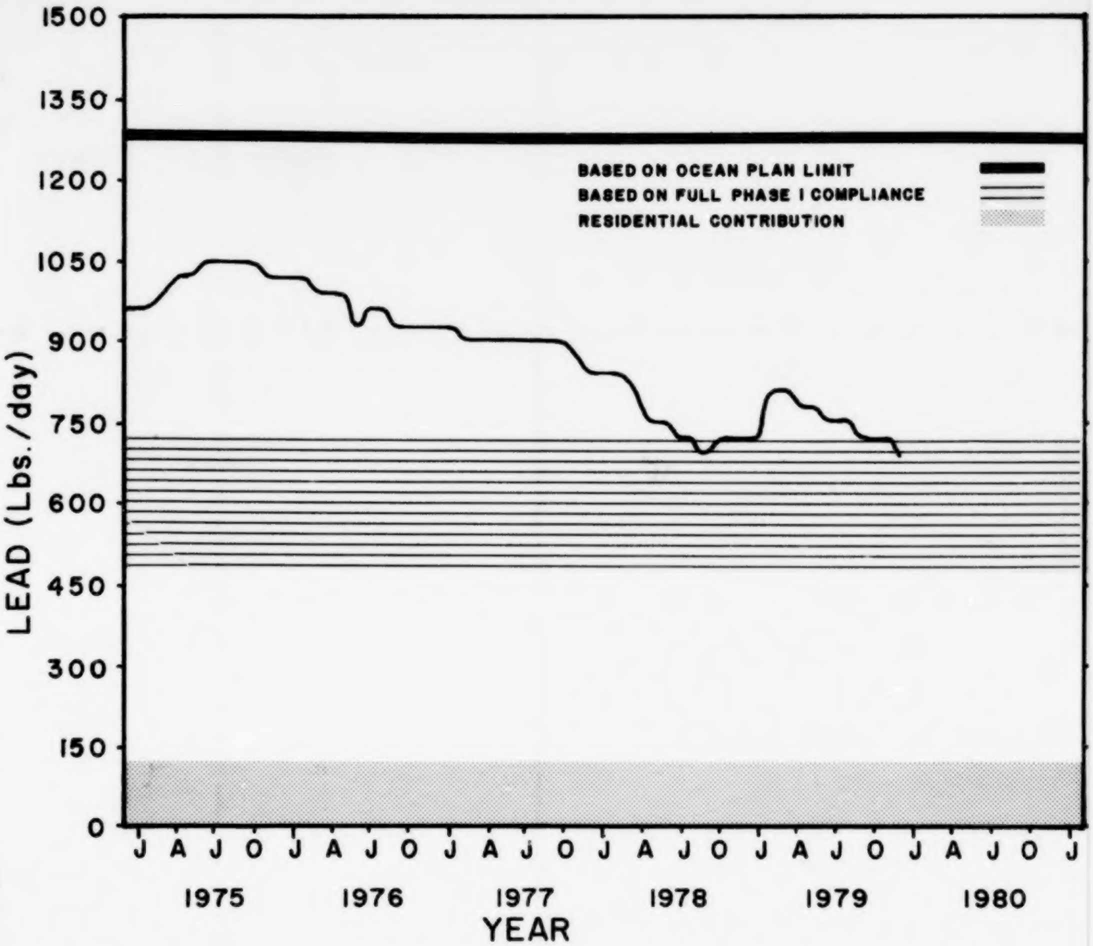


Figure 9. Mass inflow of Lead at the J.W.P.C.P.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE

TYPING GUIDE SHEET

CENTER OF PAGE

TOP OF IMAGE AREA

DROPPED HEAD; BEGIN SECTIONS HERE

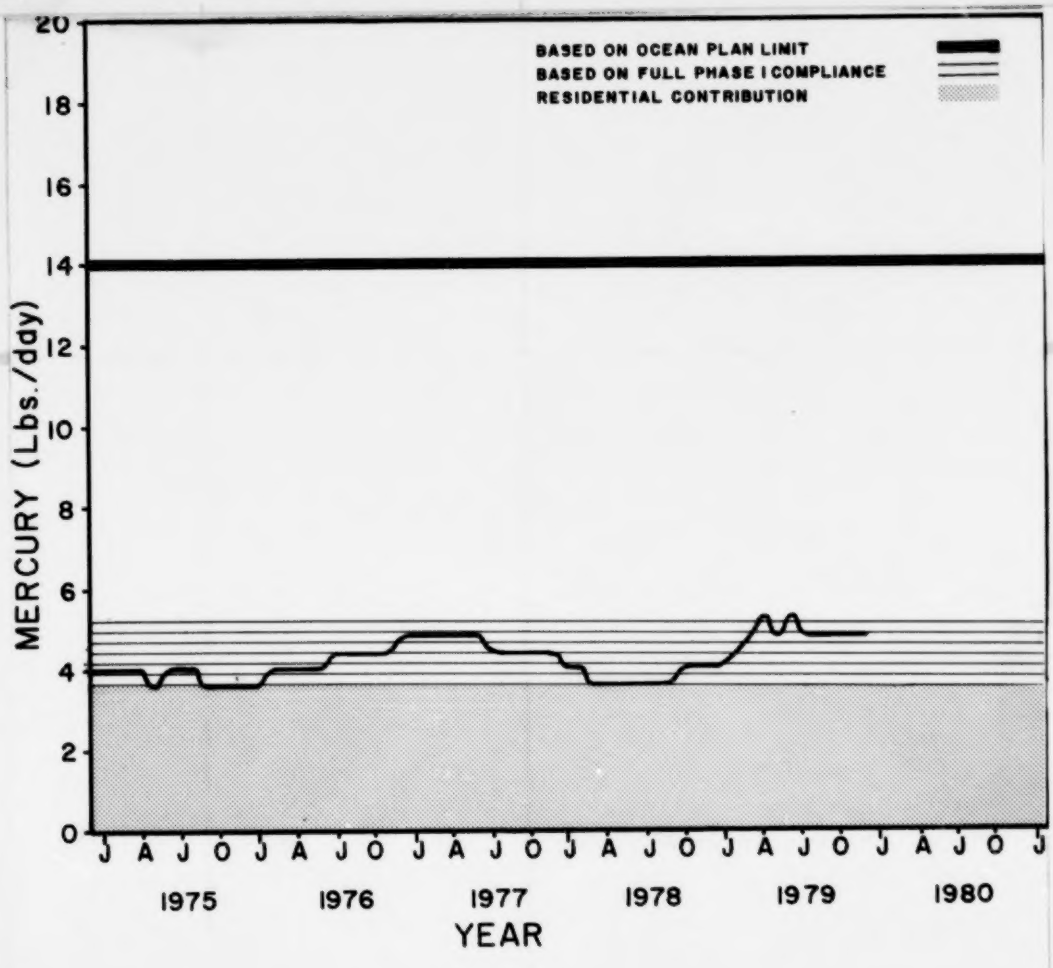


Figure 10. Mass inflow of Mercury at the J.W.P.C.P.

BEGIN LAST LINE OF TEXT

BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS

3/8"

PAGE NUMBER

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE

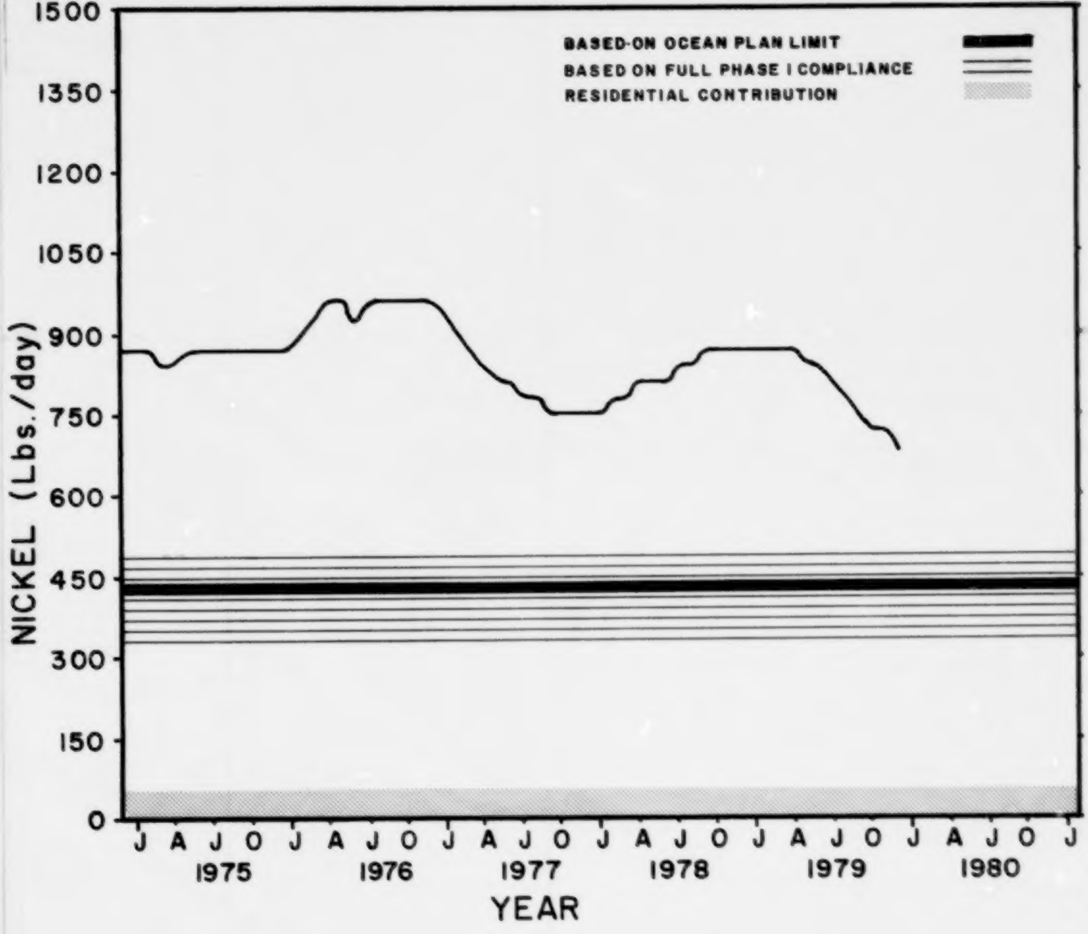


Figure 11. Mass inflow of Nickel at J.W.P.C.P.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER

EPA-287 (Cin.)
(4-76)

limit established by the original Ocean Plan. Approximately a 20% reduction has been achieved to date. It is anticipated, however, that a 50% decrease in nickel level could be achieved if all the affected industries were in compliance with the Phase I limits of 12 mg/l of nickel. More vigorous efforts will be given to the control of nickel problems in 1980. It should be emphasized, however, that with the current levels of nickel, the Districts are still able to comply with the 1978 revised Ocean Plan limit of 7,900 lbs/day. When the cyanide disposal station is closed, it is estimated that a reduction of nickel discharged of about 125 lbs/day will be obtained.

Zinc

A reduction of about 43% in the zinc level, shown in Figure 12, has been achieved to date through vigorous enforcement of the source control program. It is anticipated that an additional 10 to 15% removal will be attained if all companies are in full compliance with the Phase I limit of 25 mg/l of zinc.

Silver

Except for the increase in silver in the latter part of 1978, the mass flow of this constituent has been within the range of values expected for full compliance with the Phase I limit of 5 mg/l of silver. The period of high silver mass flow observed in 1978, which is indicated in Figure 13, was caused by one large company discharging wastewater containing silver greatly in excess of the Phase I limits. This particular discharger received a large government contract to develop photographs and performed the work without recovering large amounts of waste silver in the photo processing wastes. The company made the necessary corrective action after being notified by the Districts of noncompliance.

TICH

The total identifiable chlorinated hydrocarbons (TITCH) in the JOS are made up primarily of dichlorodiphenyltrichloroethane (DDT) and other pesticides and polychlorinated biphenyls (PCB). Figure 14 presents the mass discharge of TICH. This figure illustrates the dramatic decrease in the TICH discharge starting early in 1975. While the Districts' pressure on industries to control these constituents definitely has significant impact on the reduction of TICH, other factors that occurred prior to 1975 also contributed to this situation. For instance, after June 1971, through Districts' regulatory actions, a major DDT manufacturer ceased discharge of DDT to the JOS. Considerable amounts of DDT-laden sediments, however, remained in the sewers downstream of this company. In 1971 and 1972, several cleaning operations were undertaken which removed a major portion of the DDT-laden sediments. These cleaning operations while successful, were abandoned because it caused resuspension of fine sediments which flowed to the JWPCP and eventually discharged to the ocean.

The other major component of TICH is PCB's which are used in electrical devices, cooling devices and in microcoating of carbonless copying paper. The Districts have a continuing program to control PCB discharges, primarily

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

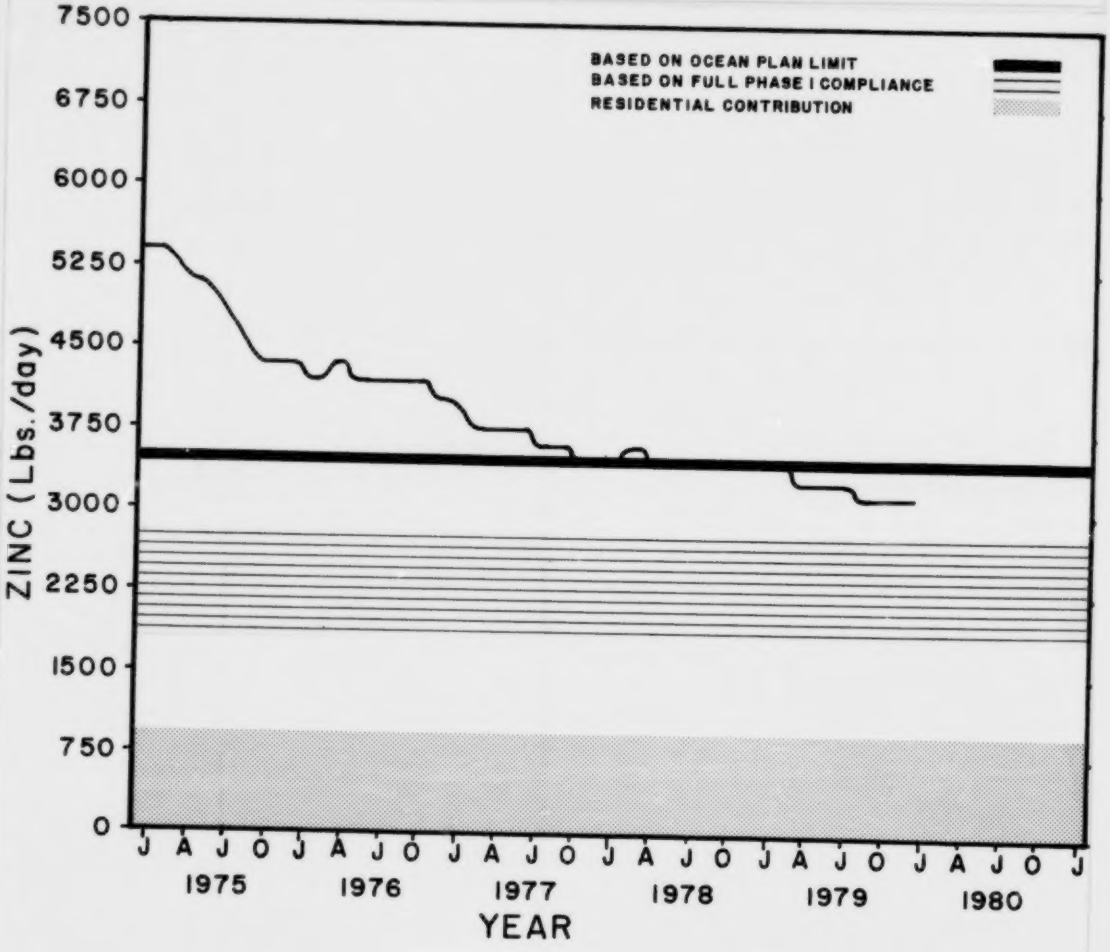


Figure 12. Mass inflow of Zinc at the J.W.P.C.P.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/16"
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

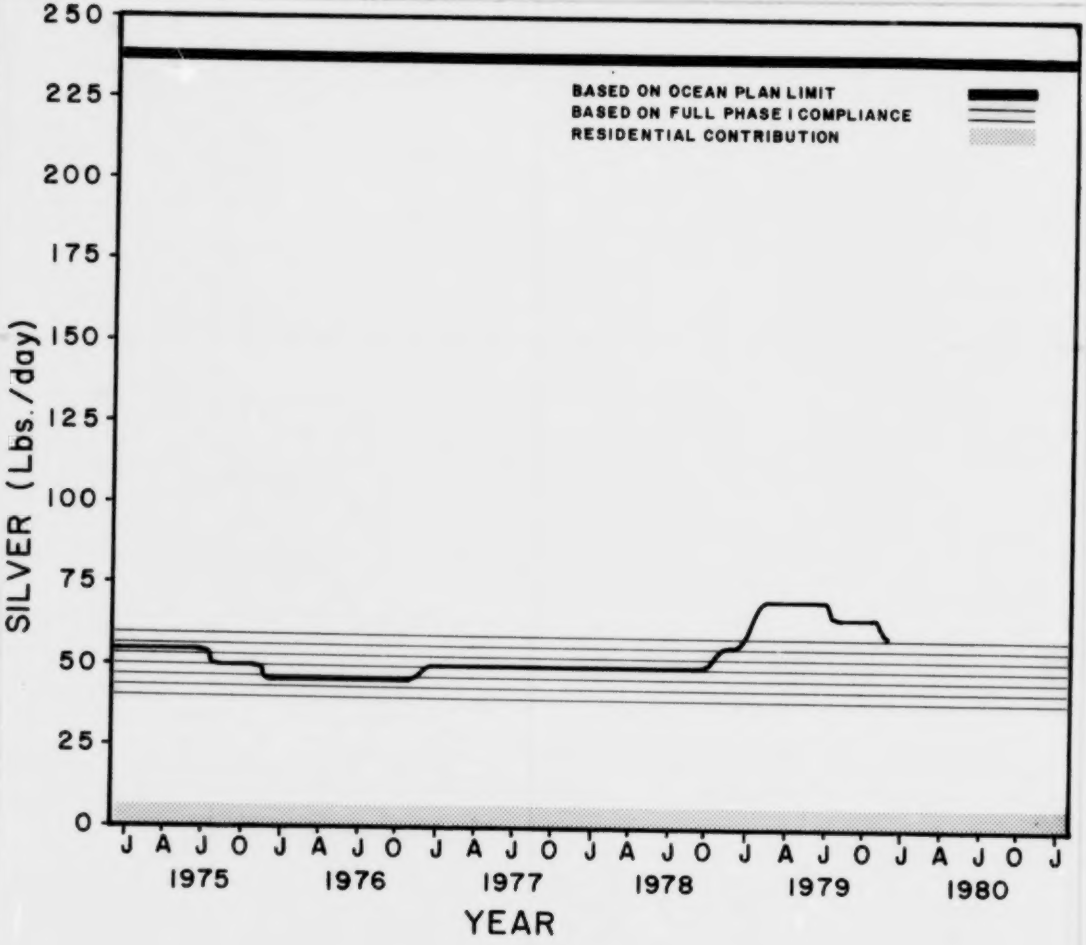


Figure 13. Mass inflow of Silver at the J.W.P.C.P.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

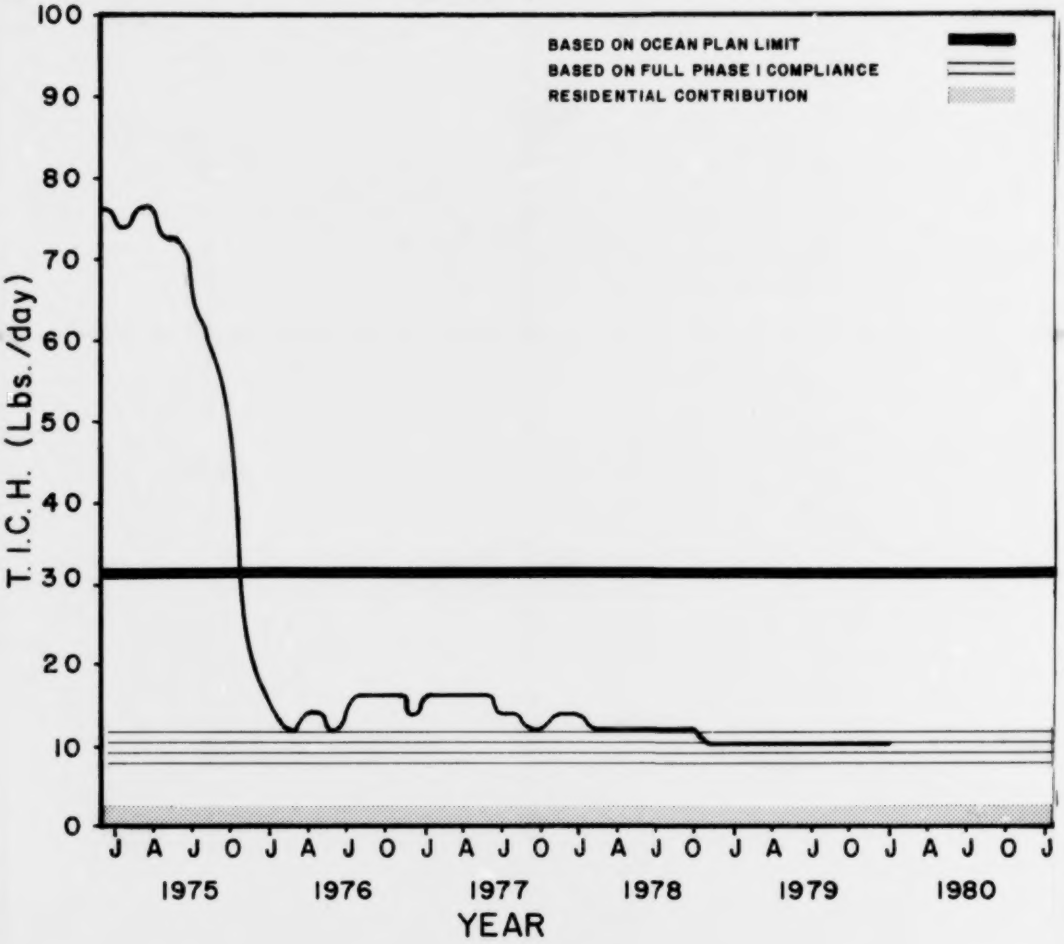


Figure 14. Mass inflow of T.I.C.H. at the J.W.P.C.P.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

from paper companies which used recycled carbonless paper and from electrical companies or companies which manufacture or repair electrical transformers or condensers which contain PCB's. The successful control of PCB is evidenced by the reduction in the mass loading from 60.1 lbs/day in 1972 to 4.9 lbs/day in 1978. The current relatively stable level of TICH at the JWPCP is considered within the anticipated range with essentially full compliance by contributing industries.

SUMMARY

To meet the water quality goals established in 1972 through the Federal Public Law 92-500 and the California Ocean Plan (Original), the LACSD Board of Directors adopted, on April 1, 1972, an ordinance regulating industrial wastewater discharges. This Ordinance established a number of industrial waste regulatory programs which include industrial waste permits, an industrial surcharge program, plant inspections, and wastewater monitoring and enforcement activities.

A major element of the industrial waste source control program is the implementation of the Phase I limits, adopted by the JOS districts on July 1, 1975 and strictly enforced since July 1, 1977. The Phase I program established industrial effluent discharge limits for cyanide, heavy metals and TICH.

The LACSD have successfully implemented the industrial waste source control program as indicated by the significant decrease in the mass inflow to JWPCP of As, Cr, Cu, Cn, Pb, Zn, and TICH. Other parameters, such as Ag, Cd, and HG, while consistently meeting the Phase I limits, have not changed significantly from 1975 through 1979. On the other hand, the Ni level has remained above the established Ocean Plan effluent limit, but should be reduced with the closure of the cyanide disposal station at JWPCP.

As of December 1979, it is estimated that about 85% of the affected industrial dischargers are meeting the Phase I limits through good housekeeping techniques. The remaining companies, however, particularly those metal platers using automatic plating equipment with high production rates, as well as those using barrel plating or processing hard to drain parts, have had to install end-of-the line treatment systems to meet the Phase I effluent limits.

The administration and implementation of the Districts' industrial waste source control program have been carried out by the Industrial Waste Section, which currently has 48 personnel, at a total cost of $1.27 million during the 1978-1979 fiscal year.

EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE

PB83-142349

COMBINED MUNICIPAL-INDUSTRIAL WASTEWATER TREATMENT IN GARLAND, TEXAS

A. Netzer(1), J. McNutt(1) and W. B. Dollar(2)
(1) Environmental Sciences
The University of Texas at Dallas
Richardson, Texas

(2) Public Works
City of Garland
Garland, Texas

ABSTRACT

The Duck Creek Wastewater Treatment Plant is a combined municipal-industrial treatment facility serving the City of Garland, Texas and portions of the cities of Sachse, Mesquite, Sunnyvale, and Dallas, Texas. The municipal effluents are from a population of over 150,000 and the industrial discharges are from over 400 various light industries, ranging from paint manufacturing and metal plating to food and dairy processing. Due to growth of both population and industry serviced by this combined municipal-industrial wastewater system, the Duck Creek Wastewater Treatment Plant was recently upgraded from its original 10 MGD biological treatment facility to a 30 MGD facility by the addition of a 22.5 MGD physical-chemical treatment process. Pretreatment consists of trash screening, a 60 MG equalization basin with brush aerators, bar screening, and grit removal. The biological treatment process consists of primary clarification, primary trickling filters, intermediate clarification, secondary trickling filters, and final clarification. The physical-chemical treatment process consists of coagulation-flocculation with lime, ferric chloride, and polyelectrolytes, clarification recarbonation, and ultra-high rate sand filtration. Final treatment for both systems consists of granular activated carbon adsorption and chlorine disinfection.

INTRODUCTION

The City of Garland, Texas is an industrial, suburban community of over 150,000 located on the northeast perimeter of Dallas, Texas in Dallas County. The industrial community located in Garland, Texas is composed of over 400 various light industries. These industries, some with very little, but most with no pretreatment, discharge their effluents into the municipal system. The influent wastewater treatment at the Duck Creek Wastewater Treatment Plant is composed of approximately 60-70% municipal and 30-40% industrial wastes.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)

Faced with an expansion of the existing wastewater treatment facility at the Duck Creek Wastewater Treatment Plant from its previous 10 MGD biological configuration, the City of Garland elected to expand the facility with the addition of 22.5 MGD physical chemical treatment process.

The pretreatment processes include trash removal with trash screens, retention in a 60 MG equalization basin with brush aerators, bar screening and grit removal.

The biological treatment configuration consists of primary clarification, primary trickling filters, intermediate clarification, secondary trickling filters, and final clarification.

The physical-chemical treatment process consists of coagulation-flocculation, clarification, recarbonation, and ultra-high rate sand filtration.

Final treatment for both systems is accomplished with the use of granular activated carbon adsorption and chlorination. Figure 1 shows the schematic diagram of the Duck Creek Wastewater Treatment Plant.

INFLUENT AND EFFLUENT CHARACTERISTICS

Preliminary influent quality studies were conducted by the design engineers at an independent laboratory (1). Data was averaged and described below in Table 1. The design of the plant expansion (the physical-chemical treatment plant) was based on these results.

TABLE 1 AVERAGE INFLUENT WASTEWATER CHARACTERISTICS

Parameter	Averaged Result
Total BOD_5 (mg/l)	266
Total COD (mg/l)	542
Suspended Solids (mg/l)	233
Alkalinity (mg/l as $CaCO_3$)	200
pH (Mean)	7.35

Recent studies by the City of Garland laboratory at the Duck Creek Wastewater Treatment Plant have the following influent characteristics for 1979 (Table 2).

EPA-287 (Cin.)
(4-76)

TABLE 2 AVERAGE INFLUENT WASTEWATER CHARACTERISTICS, 1979

Parameter	Averaged Result
Total BOD_5 (mg/l)	239
Total COD (mg/l)	540
Suspended Solids (mg/l)	233
pH (Mean)	7.10

Comparing the 1971 design-based data and the 1979 actual operational data shows the consistency of the influent to the facility.

The State of Texas permit which allows for discharge from this treatment facility has the following criteria:

Quality:

BOD_5	10 mg/l, monthly average, 24 hours daily composite, and individual samples
Total SS	10 mg/l, monthly average, 24 hours daily composite, and individual samples
Chlorine residual	1 mg/l, after 20 minutes contact time

Volume:

Average Design Flow	30 MGD	
Actual Flow Records (1979):	Maximum:	30 MGD
	Minimum:	9.5 MGD
	Average:	18.3 MGD

The discharge permit for the previous biological treatment facility was for a maximum flow rate of 10 MGD, with a BOD_5 not to exceed 20 mg/l and a SS not to exceed 20 mg/l. The upgrading of the Duck Creek Wastewater Treatment Plant to a combined, split-stream biological and physical-chemical treatment process resulted in a more stringent discharge permit from the State of Texas.

PRETREATMENT

The influent wastewater arrives at the Duck Creek Wastewater Treatment Plant via a 48" pipeline. Immediately after entry, it is passed through a 5-foot wide Jeffery Manufacturing Company mechanically cleaned trash screen. Objects removed are collected and hauled to the City of Garland landfill. The average trash removed is approximately 1000 lbs./day.

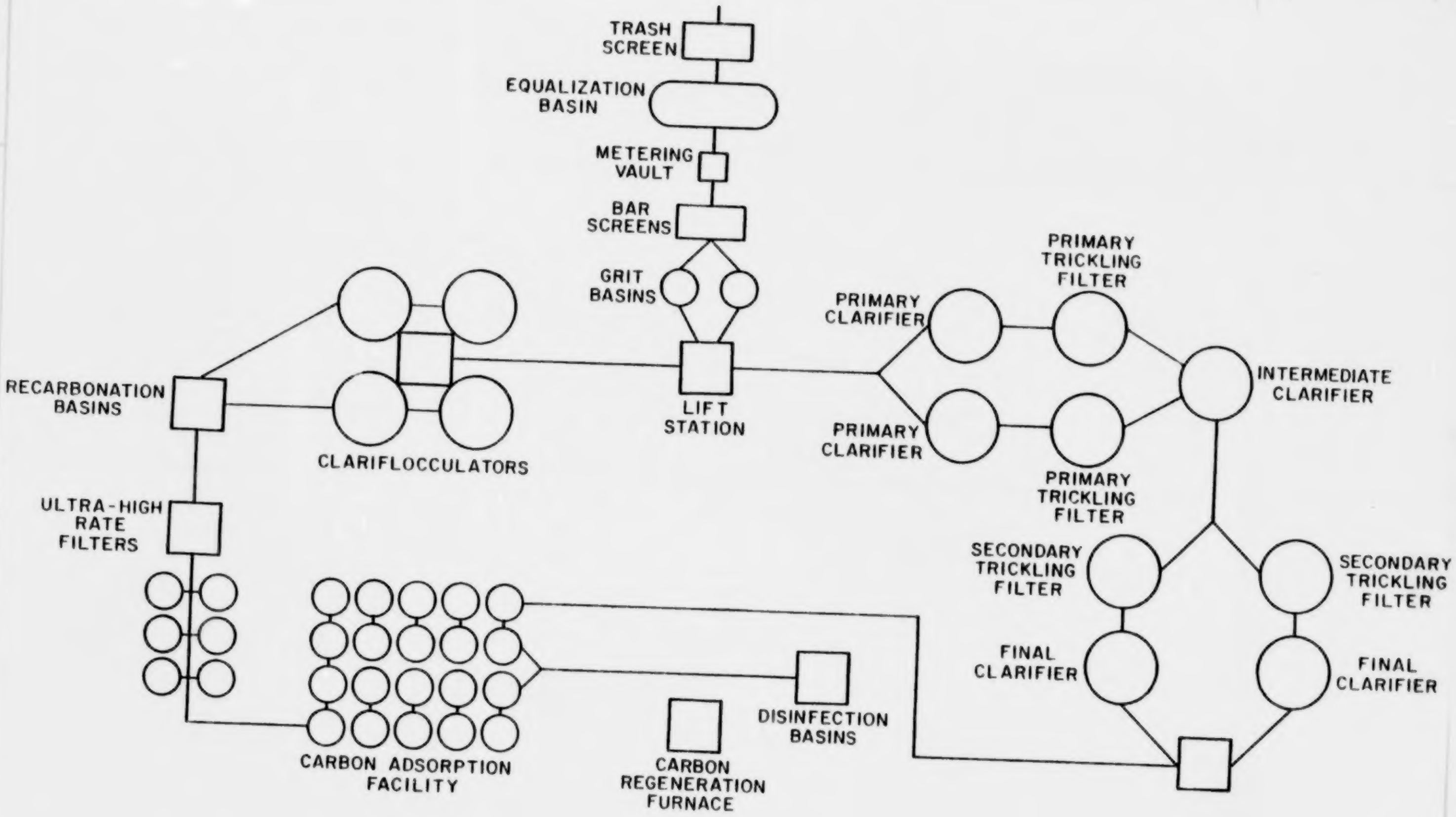

TRASH SCREEN
EQUALIZATION BASIN
METERING VAULT
BAR SCREENS
GRIT BASINS
LIFT STATION
CLARIFLOCCULATORS
RECARBONATION BASINS
ULTRA-HIGH RATE FILTERS
CARBON ADSORPTION FACILITY
CARBON REGENERATION FURNACE
DISINFECTION BASINS
PRIMARY CLARIFIER
PRIMARY CLARIFIER
PRIMARY TRICKLING FILTER
PRIMARY TRICKLING FILTER
INTERMEDIATE CLARIFIER
SECONDARY TRICKLING FILTER
SECONDARY TRICKLING FILTER
FINAL CLARIFIER
FINAL CLARIFIER

Figure I. DUCK CREEK WASTEWATER TREATMENT PLANT
SUNNYVALE, TEXAS

EPA-287 (Cin.)
(4-76)

The influent wastewater flows by gravity to a 60 MG equalization basin. The equalization basin was constructed in order to provide a uniform discharge to the treatment processes, regardless of changes in flow rate and to eliminate shock loads. The basin is oval in shape, divided down the center to provide a single pathway. The basin is 1,112 feet long, 132 feet wide, and 12 feet deep. The equalization basin is equipped with four Arvo Model 25 E flow developers to insure good mixing to eliminate solids precipitation in the basin.

The basin is also equipped with four Passavant 20-foot long Lagoon Master Floating Mammoth Brush Rotators. These brush aerators introduce oxygen into the wastewater in the basin to avoid septic conditions during the 8-hour residence time.

The wastewater flows by gravity through a meter vault for measurement, through one of two 36-inch parallel Jeffery Manufacturing Company mechanically cleaned bar screens. A third bar screen, a Jeffery Manufacturing 48-inch,hand-cleaned bar screen is available in case of mechanical failure. The bar screenings are collected and disposed of with the collected grit in the City of Garland landfill.

Immediately following bar screening, the wastewater is passed into one of two aerated grit removal basins. These basins are circular, 34 feet in diameter and 25 feet in depth. Grit is collected in the bottom of the basins and transferred to one of the two Wemclone #1000-C hydrogritter units for dewatering. The dewatered grit is collected and hauled to the City of Garland landfill. The bar screenings and grit removed average 1200 lbs./day.

The wastewater that has received pretreatment is pumped through the raw water lift station for distribution into the biological and physical-chemical treatment processes. The raw water lift station uses five pumps, two of which are variable speed. The flow rate through the raw water lift station during 1979 averaged 18.3 MGD, with a high flow of 30 MGD and a low flow of 9.5 MGD.

BIOLOGICAL TREATMENT PROCESSES

The biological treatment processes at the Duck Creek Wastewater Treatment Plant begin with two primary clarifiers, Eimco Type-C clarifiers. Each measures 75 feet in diameter, with a sidewall depth of 10 feet. The clarifiers are each equipped with two sludge rake arms.

Two primary-stage trickling filters follow the clarifiers. These are designated as Eimco high-rate trickling filters, 140 feet in diameter with a sidewall depth of 8.5 feet.

An Eimco intermediate clarifier follows the primary-stage trickling filters. The intermediate clarifier is 110 feet in diameter with a sidewall depth of 11 feet and equipped with a single sludge rake arm.

EPA-287 (Cin.)
(4-76)

Two secondary-stage trickling filters follow the intermediate clarifier. Both are Eimco high-rate trickling filters, with 140 feet diameter and a sidewall depth of 8.5 feet.

The secondary-stage trickling filters are followed by two final clarifiers. These clarifiers are 110 feet in diameter with a sidewall depth of 11 feet, equipped with two sludge rake arms.

The effluents from the final clarifiers flow by gravity into a wetwell, which is located under the biological lift station. The effluents in the wetwell are pumped by three turbine pumps to be mixed with the physical-chemical treatment effluents at one of three possible points:

1. into the wetwell prior to ultra-high rate filtration.
2. prior to the granular activated carbon adsorption
3. prior to the disinfection basin

Sludges collected during primary, intermediate and final clarification are pumped to the sludge dewatering facilities for conditioning, dewatering, and disposal. These sludges are mixed with the physical-chemical treatment sludges in the sludge equalization tanks prior to conditioning.

The biological treatment process was made operational in the Duck Creek Wastewater Treatment Plant in 1962, at a designed treatment capacity of 10 MGD. A performance loss was noted at flows in excess of 7.5 MGD. The current maximum daily flow rate through this process is now 7.5 MGD.(2)

PHYSICAL-CHEMICAL TREATMENT PROCESSES

Wastewater from the raw wastewater lift station is pumped to one of two flash mising units on the south side of the chemical building. Each flash mixing unit consists of two Lightnin 82-Q 7-1/2 hp mixers, where 140 mg/l of lime, 35 mg/l of ferric chloride, and 0.5 mg/l of polyelectrolyte are added to the wastewater. The wastewater with the chemical mix is flowed to one of four 100 feet in diameter, 14 feet in depth clariflocculators. Total retention time is 3 hours, with 30 minutes for flocculation and 2-1/2 hours for settling.(3)

The sludges are accumulated by two sludge rakes at the bottom of the clariflocculators and are pumped to the sludge dewatering facility. Floating grease and scum is skimmed and pumped back into the chemical building for incineration in one of two Walker Process Greaseburn incinerators. The current grease loading is negligible, with only one furnace operating for one day every four months.

After the wastewater passes over the weirs at the circumference of the clariflocculators, it flows by gravity to one of the two recarbonation basins. The recarbonation facility is composed of two 20 feet wide by 80 feet long by 15 feet deep basins. Each basin is divided into two parts, one mixing basin 24' in length, and one reaction basin, 56' in length. The mixing chambers each have two Rexnord Envirex 5 hp turbine spargers for addition and diffusion of carbon dioxide. A 13 foot high weir separates the mixing and reaction basins, forcing the wastewater upwards after it has received the carbon dioxide. The wastewater then flows through the 56 foot long reaction basin, passing over a final weir, and into a trough which connects both recarbonation reaction basins.

The design carbon dioxide dosage is 200 lbs./MGD, which is supposed to react with the clariflocculators effluents and lower the pH from 10.0 to 7.5-8.0. The lowered pH is most compatible with the filtration which follows the recarbonation facility.

Carbon dioxide is stored in the liquid form on site in a 24-ton storage unit equipped with an integral refrigeration unit. A dual vaporizer system insures the system will not pass liquid carbon dioxide into the effluents in the recarbonation basins.

The present situation, however, does not lend itself to the desired pH reduction. Instead, the pH reduction has at best been a reduction by only 1.4 pH units.

The University of Texas at Dallas has begun an optimization study of the recarbonation systems at the Duck Creek Wastewater Treatment Plant. A series of laboratory and field experiments have demonstrated a lack of mass transfer from carbon dioxide gas to the effluent liquid in the recarbonation basin. This lack of mixing therefore resulted in an incomplete reaction between the carbon dioxide and the calcium carbonate in the wastewater. Currently, new diffuser systems are being tested in order to improve the overall performance of the recarbonation facility.

After recarbonation, the effluents are allowed to flow by gravity flow into two wetwell facilities, each 39 feet long by 22 feet wide by 30 feet deep. These wetwells insure a continuous flow through the four ultra-high rate sand filtration system pumps, each powered by 250 hp variable speed electrical motors. The wetwells also provide a good mixing area for the biological effluents if they are added to the physical-chemical effluents prior to ultra-high rate sand filtration.

Filtration takes place in six Dravo ultra-high rate filters, each 16 feet in diameter and 16 feet high. The filters are designed to operate at a maximum flow of 22.5 MGD, using 2-3mm diameter quartz filtering sand. The bed depth is 5'6". The filters operate at 45 PSI. Backwash operations are carried out automatically every 4.5 hours, or if head loss exceeds 10 PSI. Filter backwash procedures last 15 minutes for the 4.5 hour backwash procedures, and 3 minutes when headloss exceeds 10 PSI. All six ultra-high rate sand filters feed into a central manifold, which leads to a 36", 58 feet tall stand pipe, providing head for the following granular activated carbon adsorption process and disinfection.

Although existing pipelines allow for the mixing of biological and physical-chemical effluents prior to ultra-high rate sand filtration, this procedure is utilized only in periods of climactic change where biological growth in the trickling filters is sloughing off.

EPA-287 (Cin.)
(4-76)

If the biological treatment effluents were not joined with the physical-chemical treatment effluents prior to ultra-high rate sand filtration, they are blended immediately afterwards, prior to granular activated carbon treatment.

The Zurn granular activated carbon adsorption process consists of ten sets of two basins. In each set, one basin is for upflow, the other for downflow. Each basin is 25 feet in diameter and is 20 feet high. Nine of the sets of two basins are on-line, while the tenth set is off-line for carbon regeneration or backwash procedures. The Zurn Upflow-Downflow granular activated carbon adsorption process was selected because of its higher efficiencies and lower initial and operational costs (4).

The granular activated carbon adsorption bed is 10' deep on top of a 1 foot deep gravel bed on top of the underdrain system. The design flow through the system with 10 pairs in operation is 30 MGD, with a design flow rate of 4.7 GPM/ft^2. There is approximately 118,000 lbs. of granular activated carbon in each basin. The carbon loading rate is 975 lbs./MGD. Backwash is accomplished at a rate of 15 GPM/ft^2, with air scouring at 5 CFM/ft^2. The frequency of backwash procedures has not yet been determined. The granular activated carbon in use at the facility is ICI America's Hydrodarco 3000.

The granular activated carbon facility has not yet been operated in a routine, on-line mode. The facility was operated for several weeks in 1978, with underdrain damages evident in several basins. Since that time, Zurn Industries has been involved in an in-house redesign, testing, and installation of new underdrain systems.

Carbon regeneration is scheduled for every 28 days, in an on-site Zimpro multiple-hearth, gas-fired furnace. This furnace is capable of regenerating 80,000 lbs./day at peak loading.

The Zimpro furnace has also not yet demonstrated its effectiveness. Operated for a short period of time in 1978, it lost large amounts of granular activated carbon in the regeneration process. Since that time, the Zimpro Corporation has redesigned several parts of the furnace system and hopes to test its effectiveness in late spring, 1980. In 1978, the City of Garland asked the University of Texas at Dallas to participate in studies to optimize the granular activated carbon treatment at the Duck Creek Wastewater Treatment Plant. In late spring, 1979, four pilot plants were designed and constructed near the existing carbon facility at the Duck Creek Wastewater Treatment Plant. These four 4.0 GPM pilot plants utilize upflow-downflow granular activated carbon adsorption columns, with design specifications as similar to the existing Duck Creek facilities as possible. Two pilot plants utilize granular activated carbon (GAC), one on the effluents from the biological treatment processes, the other on the effluents from the physical-chemical treatment processes. The other two pilot plants utilize the technique of pre-ozonated granular activated carbon (BAC), one on the effluents from the biological processes, the other on the effluents from the physical-chemical treatment processes. These pilot plants give the unique opportunity to study and compare the effectiveness of granular activated carbon and pre-ozonated granular activated carbon adsorption on the effluents from both

EPA-287 (Cin.)
(4-76)

biological and physical-chemical treatments. The data generated in the pilot plant studies will assist in the operation and future development of the full-scale operations. These pilot plant facilities have been operating since early November, 1979, with close monitoring by analytical laboratory testing for performance evaluation.

DISINFECTION

Disinfection is achieved by the addition of chlorine gas to the effluents as they pass into one of two parallel 130 feet long by 35 feet wide by 16 feet deep disinfection basins. Each basin is designed for a minimum of thirty minutes residence time at a flow of 30 MGD.

DISCHARGE

Discharge is via a 200 yard long, 48" pipleine from the disinfection basins into Duck Creek. Duck Creek continues for approximately one mile, and flows into the East Fork of the Trinity River just below the dam at Lake Ray Hubbard. The Trinity River flows southward for approximately 300 miles into West Bay, near Galveston, Texas and the Gulf of Mexico.

SLUDGE HANDLING AND DISPOSAL

The sludges removed from the biological and physical-chemical treatment processes are combined in two 17 feet in diameter, 9 feet tall sludge equalization tanks. These tanks each provide a total of 18 hours residence time for the sludges. Two 1 million gallon holding tanks, formerly used as anaerobic digesters, provide up to 30 days of sludge storage for periods of peak flow.

Sludges are pumped from the holding tanks into a 1100 gallon mixing tank at the rear of the dewatering facility. The sludges are conditioned with varying dosages of lime, ferric chloride, and polyelectrolyte.

After conditioning, the sludges are pumped into one of four Envirotech Model 52 sludge presses. The press will dewater the 6-7% solids entry sludge to a final sludge cake of 35-40% dry weight. The capacity of the sludge presses has been demonstrated at 130,000 lbs./day on a dry weight basis. The pressed sludges are dropped into large disposal containers and then hauled, along with the grit and screenings from the pretreatment stage by trucks to the City of Garland landfill operation located 20 miles northeast of Duck Creek Wastewater Treatment Plant. Operations showed the 1979 average sludge removal to be 90,000 lbs./day on a dry weight basis.(5)

DISCUSSION

As mentioned earlier, several areas of treatment at the Duck Creek Wastewater Treatment Plant are not yet fully operational. The physical-chemical treatment process is not yet operating in the manner it was designed. As long as recarbonation is incomplete, the efficiency of the operation will remain inadequate. Without the granular activated carbon adsorption facility,

EPA-287 (Cin.)
(4-76)

TABLE 3 ESTIMATED MAJOR PROCESS UNIT REMOVAL EFFICIENCIES (averaged)

Process Unit	Monitoring Parameter	Average Daily Flow, MGD	Influent Level, mg/1	Effluent Level, mg/1	% Removal
Equalization Basin	BOD_5	20	260	168	35
	COD		560	410	27
	TSS		233	296	**
Biological Processes	BOD_5	7.5	168	19	89
	COD		410	45	89
	TSS		296	8	97
Physical-Chemical Processes	BOD_5	12.5	168	56	67
	COD		410	100	76
	TSS		296	50	83
Ultra-High Rate Sand Filters	BOD_5	12.5	56	40	29
	COD		100	83	17
	TSS		50	14	72
Carbon Adsorption	BOD_5	20	28	10	64
	COD		64	20	68
	TSS		17	10	86
Plant Outfall	BOD_5	20	10	10	96
	COD		20	20	96
	TSS		10	10	96

** Biological activity is responsible for increased TSS level.

TABLE 4 ACTUAL MAJOR PROCESS UNIT REMOVAL EFFICIENCIES (1979 averaged)

Process Unit	Monitoring Parameter	Average Daily Flow, MGD	Influent Level, mg/1	Effluent Level, mg/1	% Removal
Equalization Basin	BOD_5	18.5	239	206	14
	COD		540	450	17
	TSS		233	206	12
Biological Processes	BOD_5	7.5	206	19	91
	COD		450	84	81
	TSS		206	18	91
Physical-Chemical Processes	BOD_5	11	206	74	64
	COD		450	201	55
	TSS		206	41	81
Ultra-High Rate Sand Filtration	BOD_5	11	74	70	5
	COD		201	154	23
	TSS		41	25	39
Carbon Adsorption	BOD_5	** NO DATA AVAILABLE			
	COD				
	TSS				
Plant Outfall	BOD_5	18.5	42		82
	COD		138		74
	TSS		22		91

** No operational data is available on the carbon adsorption facility. No operations took place during 1979.

STATE OF TEXAS DISCHARGE PERMIT

Biological Oxygen Demand, 5 day (BOD_5)	10 mg/1, monthly average 15 mg/1, 7-day average
Chemical Oxygen Demand (COD)	none
Total Suspended Solids (TSS)	10 mg/1, monthly average 15 mg/1, 7-day average
Fecal Coliform Bacteria	200/100 ml sample, monthly average 400/100 ml sample, 7-day average
Chlorine Residual	1.0 mg/1 after 20 minutes contact time
pH	6.0 - 9.0
Maximum Discharge Flow	30 MGD, monthly average 60 MGD, any single day

EPA-257 (Cin.)
(4-76)

the effluents discharged from the plant will not reach the desired COD and BOD.

Examining the anticipated removal efficiency data proposed by the design engineers as shown in Table 3, a stepwise treatment process with high removal efficiency is noted. The operational data from 1979 found in Table 4 indicates poor treatment efficiency in the physical-chemical processes. Without optimization of physical-chemical treatment and ultra-high rate sand filtration, and the use of granular activated carbon adsorption, the effluent discharges from the plant will not consistently be within the discharge permit levels.

CONCLUSIONS

The upgrading of the Duck Creek Wastewater Treatment Plant is not yet complete. It is expected that when the facility is fully operational the effluent quality will be within the required 10 mg/l of BOD and 10 mg/l of SS, resulting in a total treatment removal efficiency of 97%. The completion of these facilities, along with the optimization of the physical-chemical treatment processes will result in the treatment of the combined municipal-industrial wastewater to a level suitable for discharge permit requirements.

REFERENCES

1. Forrest and Cotton, Inc. (1971). Engineering design report on Garland wastewater treatment facilities, Duck Creek plant expansion.

2. McDuff, D. P. and Chiang, W. W. J. (1972). Physical-chemical treatment design for Garland, Texas. Applications of new concepts of physical-chemical wastewater treatment.

3. Forrest and Cotton, Inc. (1976). Operations and Maintenance Manual Duck Creek Wastewater Treatment Plant.

4. Strudgeon, G. E. and Carens, B. (1975). Upflow-downflow carbon adsorption. AIChE Conference, Los Angeles, California.

5. City of Garland, Texas (1980). Annual report of laboratory operational data, January 1 to December 31, 1979.

PB83-142356

THE TREATMENT OF COTTON WASTE IN THE MERSEY BASIN

G.M. Doughty
MSc BSc(Eng) ACGI DIC MIWES
Department of Civil Engineering
Sheffield City Polytechnic
Pond Street
Sheffield S1 1WB
England

ABSTRACT

Many of the streams of North West England, the traditional home of the UK cotton industry, are still heavily polluted by industrial discharges. Severe pollution of the River Goyt, a tributary of the Mersey, results from a cotton processing effluent, much of which is treated in admixture with domestic sewage at Whaley Bridge Effluent Treatment Works (E.T.W.). Although the works was extended in 1967 and is not hydraulically over-loaded, the acceptance of strong liquors from the Kiering operation of the cotton processor has resulted in a gross organic overload. After hydraulic balancing and neutralisation at the trade premises, a highly coloured liquor with a BOD estimated at 8000mgL^{-1} is sewered to the E.T.W. In current extension of the E.T.W. by North West Water Authority, conventional biological treatment is to be upgraded to high-rate filters followed by oxygen activated sludge (UNOX). To aid dilution of the trade effluent, two outdated downstream E.T.W.'s are to close and their process flows pumped upstream to Whaley Bridge. A high degree of flexibility is incorporated in the design with only the highly polluted flows passing through all the biological stages. The extended works have been designed with the aim of achieving a 30/20 effluent standard, although further development work is considered necessary to eliminate high colouration.

INTRODUCTION

When the Industrial Revolution came to Britain the first major industry was textile manufacture. Its factories were thus sited at the optimum location for processing and trade. Textile treatment requires copious volumes of soft water for wet processing operations such as scouring, bleaching, dyeing and printing and this consideration was the most significant factor in the siting of the early factories and subsequent establishment of manufacturing centres.

EPA-287 (Cin.)
(4-76)

Prime sites were found beneath the Pennines of the North of England and the textile manufacturers became established in the upper and middle reaches of the river valleys of Lancashire, Yorkshire and North Derbyshire. Wool processing grew to become the dominant industry of much of Yorkshire, locating on rivers flowing out to the North Sea. The cotton industry, on the other hand, centred on the North West city of Manchester with its wet processing operations being carried out on the west flowing rivers, mostly those draining into the upper Mersey basin.

Intensive industrialization of this nature inevitably led to conditions of gross pollution which, in many cases, still remain to be improved today. The Rivers Irwell and Mersey and many of their major tributaries carry excessive loads of wastewater, much of which originates from trade premises. Lumb (1) described these rivers in 1965 as among "the most heavily worked in the UK and probably in the world."

The textile industry contributed an aggregate daily volume of 140,000 m^3 of directly discharging effluent from 59 premises in 1964 into the Mersey basin (1). Contraction of the industry and/or the diversion of discharges to sewer had reduced the number of direct discharges to eight by 1978 with an aggregate input of 36,000 m^3 (2). Hazel (3) estimated that in 1978 only 12% was discharged to stream following treatment on site with the remainder being discharged to sewer untreated or following pre-treatment such as settling or balancing.

The upper Mersey catchment drains to the Manchester Ship Canal where pollution problems are aggravated by sluggish flow in a deep artificial channel resulting in enhanced settlement and low re-aeration potential.

EFFLUENTS FROM COTTON PROCESSING

Liquid effluents result from chemical treatment which may conveniently be separated into fibre preparation and material colouration and finishing. Preparatory processes remove unwanted substances from the raw cotton while colouration and finishing involves dyeing or printing and the incorporation of finishing agents such as crease or flame retardants.

Much effort continues to be made internationally into the removal of dyewastes (4) (5) and increased stringency over discharges has led to an awareness of effluent problems when selecting dydstuffs and process methods (6).

Table 1 shows quoted characteristics of mixed effluents derived from the complete processing of cotton. The variations displayed show that operations differ markedly and, indeed, consideration of mixed effluents in this way may not be the most appropriate method of assessing their effects and treatment requirements.

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD, BEGIN SECTIONS HERE

TABLE 1 CHRACTERISTICS OF MIXED COTTON EFFLUENTS

Reference	Quantity Discharged (m^3/kg cotton)	(mgl^{-1})	pH
Lumb (1) (UK)		250- 400	7-9
Parish (7) (UK)	0.06-0.5	100- 500	8-12
Gardiner & Borne (12) (UK)		200-1800	4-12
Anderson & Wood (8) (AUS)	0.2	600-1000	10

Many establishments do not carry out a full range of processing and it is useful to refer briefly to the type of operations carried out to isolate those preparatory processes which produce difficult effluents. It is these processes which produce difficult effluents. It is these processes which appear to cause the most intractable problems in the Mersey Basin.

Raw cotton fibres contain up to 10% w/w of fats and waxes and are subject to kiering (scouring) by boiling with sodium hydroxide and sodium carbonate, often under pressure. A large proportion of the impurities are thus removed producing a kier liquor effluent described by Best (9) as of small volume but strongly alkaline and with a high organic load. Kier liquors are often costly and difficult to treat to a reasonable standard. Table 2 shows several analyses of kier liquors showing general agreement of their strongly alkaline nature and extremely high organic load in the U.K. and Australian effluents.

After scouring, the cotton is bleached using hypochlorite, chlorite, or hydrogen peroxide to remove or destroy natural colouring matter. It is usual for the kiering and bleaching operations to be carried out on the same premises although the respective effluents may be kept separate for treatment and disposal purposes.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

TABLE 2 CHARACTERISTICS OF KIER LIQUORS

Reference	Quantity Discharged (m^3/kg cotton)	BOD-5 (mgl^{-1})	PV-4hr (mgl^{-1})	pH	Others (mgl^{-1})
Lumb (1) (UK)		7100 -11000	3500 -6000	12-13	
Wheatland (10) I (UK)		10650	8850		Alkalinity 16750 (as $CaCO_3$)
Wheatland (10) II (UK)		6650	6000		
U.S.H.E.W. (11) (US)	0.003 -0.017	680-2900		10-13	
Anderson & Wood (8) (AUS)	0.004	8000-14000		13.5	Sodium 11000-13000

TREATMENT OF COTTON EFFLUENTS

Successive legislation from the 1937 Drainage of Trade Premises Act and resulting practice has maintained that, where feasible, trade effluents are best treated in admixture with domestic sewage in municipal treatment plants. Re-organization of the water industry in England and Wales in 1973 created larger units with the resources to adequately plan and expedite wastewater treatment. Rhoades (13) suggests that treatment at a municipal works with suitable control is the best course of action for textile wastes. Australian practice involves primary treatment on site with subsequent discharge to sewer (8). The tendency in the Mersey Basin in recent years has been to divert more textile effluent to sewer and, in most cases, a satisfactory effluent has been achievable.

Wheatland (10) describes the effect of adding 3800 m^3day^{-1} of mixed textile effluent on the performance of a U.S. biological (trickling) filter plant previously treating only domestic sewage. It can be seen that although the volumetric loading increased by less than 10% the increased organic loading and loss of efficiency of the primary unit led to a doubling of load upon the biological stage. Since this load is about five times that normally used for a UK plant (no recirculation) it is not surprising that the reduction in effluent quality resulted.

TABLE 3 EFFECT OF TEXTILE WASTE ON SEWAGE WORKS PERFORMANCE

	Before addition of textile effluent	After addition of textile effluent
Volumetric Load $(m\ day^{-1})$	40.9	44.7
BOD of raw sewage (mgl^{-1})	290	450
BOD removal in primary sedimentation (%)	27	18
Loading on filters $(kgBOD/m^3 day)$	0.30	0.59
Overall BOD removal (%)	83	79
BOD of final effluent (mgl^{-1})	49	95

Indeed, if textile wastes are to be treated by aerobic biological treatment, nutrient requirements may indicate that an admixture with domestic sewage is desirable. Many enzymes require specific activators to satisfactorily accomplish reaction. One of the most important activators is the phosphate ion which may be deficient in textile waste whereas it reaches relatively high concentrations in domestic sewage (7) (10). The beneficial effects of nutrient balance in conjunction with buffering and dilution are therefore obtained by treatment in admixture with domestic sewage.

Many textile wastes have a high pH and neutralization may be necessary prior to discharge to sewer. A pH level of up to 9.5 may be tolerated for wastes applied to biological filters provided alkalinity levels are not excessive (10). Recirculation of filter effluent will provide some dilution while CO_2 production within the filter will afford further neutralization. Suspended culture processes may tolerate higher pH values in the effluent because of the inherent buffering action of completely mixed plants. However, the pH of the activated sludge mixed liquor should not exceed 8.5 (10).

Treatment of Kier Liquors

It is not surprising that kiering effluent, with such high organic concentrations in conjunction with extreme alkalinity (as shown by table 2), has been the subject of considerable attention.

Treatment methods may conveniently be divided into two types, those where the concentrated liquor is treated or pre-treated separately from any other effluents, and those where the concentrated liquor is treated or pretreated separately from any other effluents, and those where dilution and/or mixing with other waste streams followed by more conventional treatment is practiced.

Wheatland (10) suggests that kier liquors may be sufficiently strong to consider evaporation followed by incineration of the residues. Both Franklin (14) and Little (15) discuss the neutralization of strong alkaline wastes with flue gases in packed towers. Sulphuric acid has also been used as the neutralizing agent (15) but Gardiner (12) warns of the dangers of excessive sulphate discharge to sewer causing disruption of concrete.

A series of experiments carried out on kier liquors at the Water Pollution Research Laboratory are reported by Wheatland (10). Partially neutralized liquors with an average BOD of 2200 mgl^{-1} and 4 hour P.V. of 900 mgl^{-1} were subjected to continuous anaerobic digestion at $30^{o}C$. For retention periods between 2.6 and 6.1 days, average BOD removal was 72% and P.V. removal 54%. Although the high temperature of kier liquor effluent is advantageous to digestion the probable requirement for subsequent aerobic processing has meant that little development in this area has taken place.

Aerobic treatment of diluted neutralized liquor in a laboratory scale activated sludge plant was also carried out at W.P.R.L. (10). Results showed BOD removal efficiencies of 95% at loading rates of 0.46 kg BOD/m^3 day, slightly lower than those used in conventional UK domestic treatment. Reduction of P.V. was only 35%, however, suggesting that a substantial proportion of organic matter may not be easily degradable by activated sludge.

Further reduction of P.V. was achieved by acidifying with sulphuric acid down to pH2 where substantial precipitation of organic matter takes place upon settlements as shown by table 4. The characteristic kier liquor colour which tends to be virtually unaffected by aerobic treatment is shown to be very effectively reduced by acidification and settlement.

Colour removal may also be achieved by chemical oxidation. This may be effected by using chlorine as ozidizing agent although concentrations up to 750 mgl^{-1} may be required, making the operation costly and difficult (10). Additionally, the products of chlorinating such wastes are often non-biodegradable and chlorinated organics generally are the subject of much current discussion as to potential health hazard. Alternative oxidizers are hydrogen peroxide and ozone which, although more expensive, give rise to no undesirable compounds. Additionally it is reported by Lumb (1) that the use of a peroxide bleach process reduces the BOD of the resulting liquor by 50-90% compared with the traditional caustic kier scour.

TABLE 4 EFFECT OF ACIDIFICATION & SETTLEMENT ON EFFLUENT FROM TREATMENT OF DILUTED, NEUTRALIZED KIER LIQUOR IN ACTIVATED SLUDGE PLANTS (10)

pH value after acid addition	Volume of sludge after 1 hr settlement (%)	Supernatant Liquor after 1 hr settlement		
		4-hr P.V.	Colour	Optical† Density
8.2*	2.5	300	Dark brown	1.21‡
3.5	8.5	210	Dark amber	1.03
2.8	13.0	128	Light amber	0.43
2.4	15.0	114	Light amber	0.33
2.0	16.3	107	Light amber	0.30

* before any acid addition

† using 1-cm cell, blue filter

‡ value for 1 : 1 dilution in distilled water

THE COTTON INDUSTRY IN THE MERSEY BASIN

The Mersey Basin drains a catchment of some 4585 km^2 of the heavily industrialized North West of England into the Irish Sea. It is the upper parts of this catchment drained by the non-tidal Mersey (680 km^2) and the Irwell (710 km^2) which attracted the cotton processors and their resultant effluents.

Figure 1 shows the river quality classifications at selected points as determined by North West Water Authority (2). The classifications are on a scale 1-4 recommended by the U.K. National Water Council (16), Classes 1A and 1B referring to high quality waters (eg BOD <2) and Class 4 waters being grossly polluted and likely to cause nuisance. It can be seen that both the Irwell and the non-tidal Mersey are suffering serious pollution prior to entry to the Manchester Ship Canal.

Direct Discharges

Published direct discharges into the upper Mersey basin from textile processors are detailed in table 5 and their locations, indicated by number on figure 1, are now confined to two principle sections, the upper Irwell (manufacturers 1-4) and the Goyt(manufacturers 5-8).

Those manufacturers on the upper Irwell are all located on essentially unpolluted tributory streams which suffer gross pollution below the trade waste outfall. It is apparent that each trader regularly discharges effluent with pollutant concentrations in excess of the consented values with the possible exception of Whitecroft (no. 4). Besides having the largest discharge in volumetric terms, however, Whitecroft enjoys unusually relaxed quality standards and is the largest polluters of the four traders in terms of organic load.

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD. BEGIN SECTIONS HERE

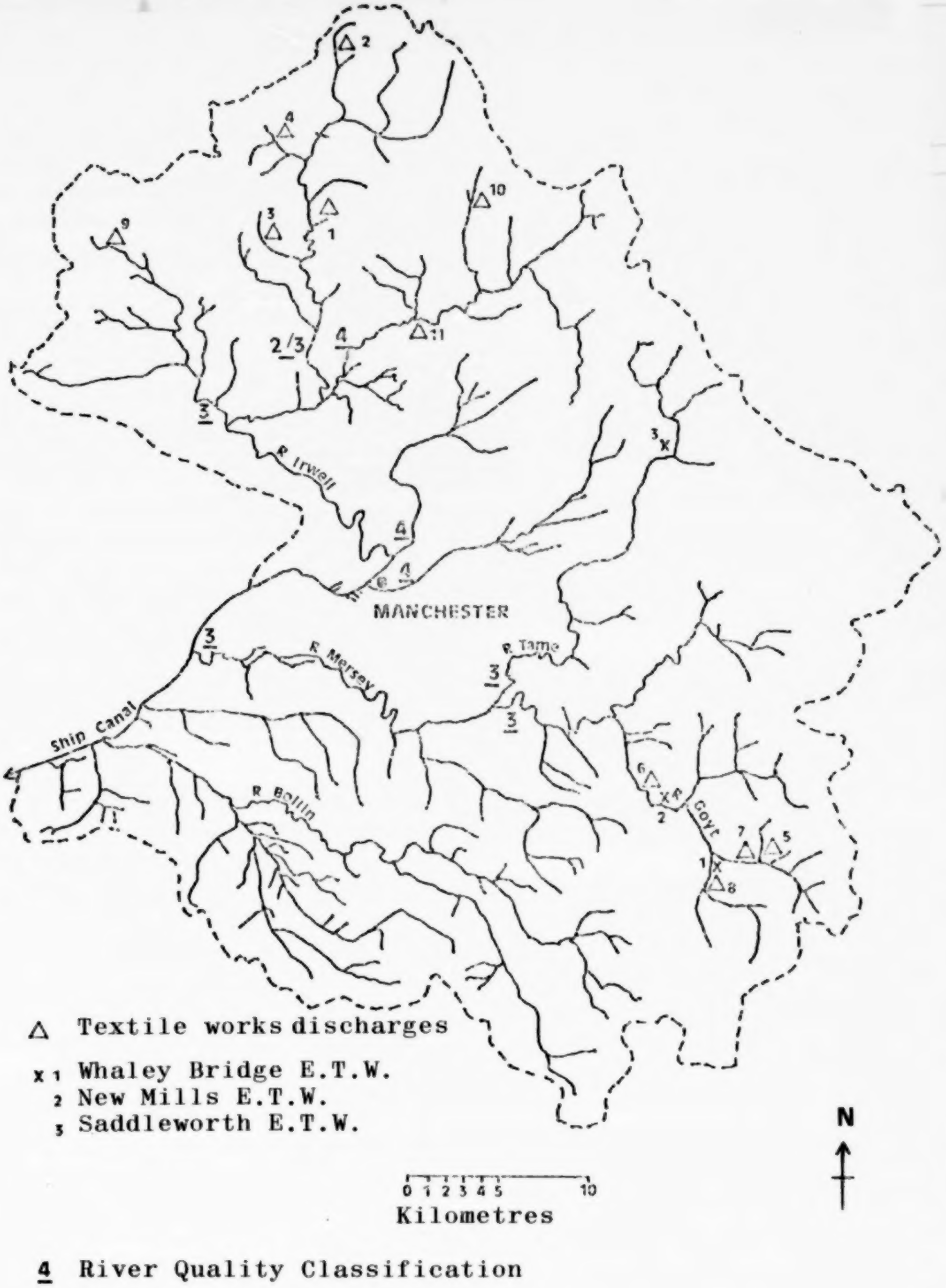

R. Irwell
MANCHESTER
R. Mersey
R. Tame
Ship Canal
R. Bollin
R. Goyt
2/3
4
3
Textile works discharges
x 1 Whaley Bridge E.T.W.
2 New Mills E.T.W.
3 Saddleworth E.T.W.
0 1 2 3 4 5 10
Kilometres
N
4 River Quality Classification

Figure 1 The Upper Mersey Catchment

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
PAGE NUMBER
EPA-287 (Cin.)

Whitecroft's Whaley Bridge discharge (No. 8) into the Goyt has a relatively satisfactory performance in terms of consent conditions but again has the largest volumetric flow. Most of Whitecroft's process flow is taken from the upstream Goyt water which is of a suitably high quality for potable supply abstraction. In so doing, the factory often removes the bulk of the flow of the Goyt causing available dilution for trade effluent to be less than 1:1 and often negligible under summer low flow conditions. The inevitable result of such a discharge and, indeed, more pertinently, of such consent conditions, is a Class 4 grossly polluted stream.

It is of interest to compare the position of Whitecroft's Whaley Bridge operation with the Strines factory of Tootal (No. 6), which is situated some four kilometres downstream. Whitecroft carries out elementary treatment (balancing tanks) prior to its direct discharge with stronger effluent liquors discharged to sewer. Tootal is subject to a similar level of consent condition on the discharge from an activated sludge treatment plant treating the entire process effluent after neutralization and hydraulic balancing. However, the available dilution at the Tootal outfall is around 20:1 and no change in river quality classification results from the discharge. Additionally, Tootal abstracts process water from the Goyt but, without the benefit of an unpolluted river source, must suffer additional costs to treat to an acceptable standard for process use. Modifications to the Tootal plant following its poor operation in 1978 (Table 5) resulted in a much improved performance in 1979. Effluent quality as derived from Water Authority samples gave mean parameter values in 1979 of 25 mgl^{-1} SS, 17 mgl^{-1} BOD, 44 mgl^{-1} 4 hr PV, and 7.8 pH (17).

The two other direct discharges on a tributary of the Goyt (Nos. 5 and 7) were consistently outside consent conditions and were both the subject of successful prosecution by the Water Authority in 1978 under statutory pollution control legislation.

TABLE 5 TEXTILE EFFLUENT DISCHARGES TO SURFACE WATERS 1978 (16)

Manufacturer	Receiving Stream & Classification	Volume (m^3/d)		Significant Quality Parameters (mgl^{-1}) SS	BOD	PV	pH
1 Ramsbottom Co. (Bleaching and Dyeing)	Trib. Irwell	Consented 3550	Consent	40	40	60	5-9
	Upstream 1B Downstream 4	Actual 450	Sample mean	188	453	177	10.8
2 Tootal, Rawtenstall (Printing and Dyeing)	Trib. Irwell	Consented 5900	Consent	30	20	40	5-9
	Upstream 1A Downstream 4	Actual 5900	Sample mean	78	43	55	8.7
3 Viyella, Ramsbottom (Dyeing)	Trib. Irwell	Consented 900	Consent	30	20	60	5-9
	Upstream 1B Downstream 4	Actual 450	Sample mean	272	54	90	7.4
4 Whitecroft, Haslingden (Bleaching and Dyeing)	Trib. Irwell	Consented 8430	Consent	60	140	120	5-9
	Upstream 1A Downstream 4	Actual 7390	Sample mean	88	101	84	7.5
5 † Dorma, Chinley (Printing)	Trib. Goyt	Consented 1590	Consent	40	40	60	5-9
	Upstream 1B Downstream 4	Actual 1590	Sample mean	131	270	160	6.2
6 Tootal, Strines (Printing and Dyeing)	Goyt	Consented 7950	Consent	30	40	40	5-9
	Upstream 3 Downstream 3	Actual 4540	Sample mean	219	79	90	7.9
7 Wardle, Chinley (Dyeing)	Trib. Goyt	Consented 2270	Consent	40	40	60	5-9
	Upstream 4 Downstream 4	Actual 2270	Sample mean	202	146	100	7.2
8 Whitecroft, Whaley Bridge (Bleaching and Dyeing)	Goyt	Consented 18300	Consent	40	-	30	5-9
	Upstream 1A Downstream 4	Actual 13640	Sample mean	29	-	22	6.7
9* Belmont, Bolton (Bleaching and Dyeing	Trib. Irwell	Consented -	Consent	30	20	40	5-9
	Upstream 1 Downstream 2	Actual 6820	Sample mean	116	480	107	10.7
10* Mycock, Whitworth (Printing and Dyeing)	Trib. Irwell	Consented 1820	Consent	40	40	60	5-9
		Actual 1820	Sample mean	99	364	233	8.3
11* Roe Acre, Heywood (Dyeing and Finishing	Trib. Irwell	Consented 273	Consent	30	20	40	5-9
	Upstream 4 Downstream 4	Actual 370	Sample mean	64	39	68	7.6

* 1976 data. Effluents now diverted to sewer.

† 1977 data. No publication Authorized in 1978.

Discharges from E.T.W.'s Treating Textile Wastes

TABLE 6 WATER AUTHORITY E.T.W. DISCHARGES (2) (18)

E.T.W.	Receiving stream & Classification	Year	Actual D.W.F. (m^3/d)	% of design	Mean* BOD	(mgl^{-1}) SS
1 Whaley Bridge	R. Goyt Upstream 3	1976	2270	66	78	47
	Downstream	1978	3450	101	70	55
2 New Mills	R. Goyt Upstream 3	1976	2120	180	104	96
	Downstream	1978	2120	180	277	107
3 Saddleworth	R. Tame Upstream 3	1976	4440	58	67	57
	Downstream 3	1978	3890	51	30	32

* All works subject to consent conditions of 20 mgl^{-1} BOD and 30 mgl^{-1} SS.

The sequence of major discharge points into the upper section of the R. Goyt is shown in Figure 1. One kilometre below the Whitecroft trade discharge, the river receives the effluent discharge from the Whaley Bridge E.T.W. which treats the neutralized concentrated kier liquors derived from Whitecroft in admixture with domestic sewage. Although commissioned as late as 1967, the works, operating with conventional biological filters, has consistently failed to function satisfactorily.

Data relating to the works performance in recent years is presented in Table 6, showing that despite being hydraulically underloaded for the most part, a poor effluent is discharged. This effluent is additionally highly coloured because of poor colour removal from the kier liquors.

A rather better performance has recently been obtained from the Saddleworth E.T.W. (Table 6) which discharges into the Tame, the other major tributary of the Upper Mersey. Saddleworth also treats kier liquors in admixture with domestic sewage,but two-stage biological treatment is used. After high-rate activated sludge treatment,the process stream is applied to low-rate biological filters. The works, which was last extended in 1972, is also hydraulically underloaded. Experiments currently proceeding are aimed at improving nutrient levels to the filters.

The relative improvement in the Tame in recent years compares with the condition of the Goyt which, despite the closure of several major direct discharges on an important tributary stream, has shown little overall change. Table 7 demonstrates the alteration in pollution load since 1964 when Lumb (1) estimated that three-quarters of the BOD load in both rivers was due to textile effluents.

TABLE 7 COMPARISON OF THE RIVERS TAME AND GOYT

River	Year	Mean values	(mgl^{-1})	
		COD	BOD	BOD (ATU)
Goyt (above confluence with Tame)	1964-5 (1)		8.1	
	1972-3 (19)	36.0	6.4	
	1976 (2) (18)	33.8	5.8	
	1977 (2)	33.8		4.0
	1978 (2)	39.4		5.9
Tame (above confluence with Goyt)	1964-5 (1)		37.0	
	1972-3 (19)	98.0	16.3	
	1976 (2) (18)	71.2	14.6	10.1
	1977 (2)	64.5		9.6
	1978 (2)	61.8		8.6

THE UPPER GOYT PROBLEM

The pollution of the upper Goyt is compounded downstream of Whaley Bridge by poor quality effluents from outdated effluent treatment works. Table 6 shows the extremely poor quality of the effluent from the worst offender of these, the New Mills E.T.W. This works was last extended in 1927 and suffers from inadequate capacity and breakdown of the trickling filter media. Although no textile waste is received by New Mills E.T.W., the influent includes a significant contribution from a confectionery manufacturer and has an organic load somewhat higher than normal domestic levels.

In 1970, consulting engineers were engaged by New Mills Urban District Council* to prepare outline design for a new works to replace the New Mills E.T.W. and a smaller outdated nearby works. The following year, only three years after the commissioning of Whaley Bridge E.T.W., Mersey and Weaver River Authority* engaged the same consultants to investigate the feasibility of transferring sewage from Whaley Bridge to a central works at New Mills, a scheme which the Authority considered to be the most desirable solution to a deteriorating situation. The consultant reported (20) that major problems at Whaley Bridge resulted from the discharge to sewer from the Whitecroft factory of an effluent with a BOD of up to 8000 mgl^{-1}. By inspecting flow records at the trade premises, the consultants ascertained that in late 1971, the trade flow was around 450 m^3/day whereas an allowance of only 140 m^3/day had been made in the E.T.W. design. This higher trade flow had resulted in an increase in organic loading by a factor of 2.6 in only four years (19).

In 1977, North West Water Authority gave formal notice that the concept of a new regional works at New Mills had been abandoned and that Whaley Bridge E.T.W. was to be extended to cater for the abandonment of New Mills E.T.W. and for the increased trade discharges.

---

*Prior to 1974 sewage treatment was carried out by elected Local Authorities and river quality control was the responsibility of River Authorities. In 1974, both funcations (and water supply) came under the auspices of the newly-created North West Water Authority.

The Current Whaley Bridge Scheme

There are two obvious disadvantages to the Water Authority scheme to improve Whaley Bridge E.T.W. rather than build a new central works at New Mills. The previous scheme had essentially gravity flow to New Mills, whereas a pumping main will carry what is hydraulically the larger proportion over a distance in excess of 2 km. Additionally, when the New Mills sewage is added to the Whaley Bridge component it will reduce the available dilution at the Whaley outfall to about 6 to 1. Over 10 to 1 dilution would be available to a regional New Mills E.T.W. with a similar throughput.

The scheme, costing some £3 m at 1978 prices, includes two stage biological treatment as did the previous consultant's recommendation for a new New Mills works (19). High rate (roughing) biological filters were proposed as pre-treatment to standard rate filters with re-circulation at New Mills. Roughing filters will also be employed in the Whaley Bridge plan by adapting and augmenting the existing filters, with pure oxygen activated sludge treatment following. Describing studies on mixed textile waste, Wheatland (10) reports that the best BOD removal efficiencies were achieved where the waste was mixed with domestic sewage and passed through roughing filters followed by activated sludge treatment.

The proposed Whaley Bridge extension provides a high degree of flexibility with the ability to keep the two streams separate through much of the works. The design loadings are shown in Table 8 with some 70$ of the highly polluted Whaley Bridge stream passing through the roughing filters. The carbohydrate-rich New Mills stream is then mixed with the total Whaley Bridge flow affording dilution and nutrient-enrichment prior to the UNOX pure oxygen activated sludge plant. Assuming BOD removal efficiencies of 85% and 95% in the roughing filters and UNOX respectively, a final effluent BOD of 20 mgl^{-1} is obtainable. The expected removal rate on the filters may appear optimistic but a loading rate of only 0.36 kg BOD/m^{3}day is to be applied, about double the conventional (low-rate) UK loading for normal domestic sewage on a filter with 1 : 1 re-circulation facility.

TABLE 8 DESIGN LOADINGS TO PROPOSED EXTENDED WHALEY BRIDGE E.T.W.

Process Stream	D.W.F. (m^3/day)	(mgl^{-1})	BOD (kg BOD/day)
Whaley Bridge stream (primary settled)	3318	1182	3923
(a) Influent to filters	2318	1182	2741
Filter effluent (assuming 85% BOD removal)	2318	177	411
(b) By-passing filters	1000	1182	1182
Ex W.B. stream to UNOX A.S.	3318	480	1593
New Mills stream (primary settled)	4636	323	1497
Influent to UNOX A.S.	7954	388	3090
Final Effluent (assuming 95% BOD removal in UNOX)	7954	20	159

The plant improvements are expected to have little effect on effluent colouration and further experimental work is proceeding to this end. As described earlier, any ameliorative provision will involve considerable further expenditure. An effluent target of 20 mgl^{-} BOD is not a particularly ambitious one for an available dilution of 6 to 1 and may reasonably be regarded as little more than a holding operation in times of considerable pressure on public funds, although it is envisaged that more of the Whitecroft direct discharge may be diverted to sewer in the future.

The reader may have some justification in questioning the wisdom of allowing the highly polluting kier liquors to sewer rather than enforcing full treatment or more sophisticated pre-treatment at the trade premises. The answer to that may lie rather more with the legal and financial commitments made between the trader and the Water Authority's predecessors than with consideration of technical feasibility.

ACKNOWLEDGEMENTS

The author wishes to express thanks to the Sheffield City Polytechnic for permission and assistance to present this paper and to Mr. Michael Lawford of Tootal Ltd and Mr. Bill Hadfield and other staff of the North West Water Authority for their assistance and helpful advice in its preparation.

EPA-287 (Cin.)
(4-76)

REFERENCES

1. Lumb, C. Pollution by Textile Effluents in the Mersey Basin, Shirley Institute pamphlet no. 92, 60-76, Manchester, 1965.

2. Water Quality Review 1978, North West Water Authority, Warrington, 1979, 345 pp.

3. Hazel, B.G. Water: An Expensive Solvent, J. Soc Dyers & Colourists, 94, 7, 289-293, 1978.

4. Waters, B.D. Treatment of Dyewaste, Wat. Pollut. Control, 78, 1, 12-26, 1979.

5. Weeter, D.W. & Hodgson, A.G. Dye Wastewaters; Alternatives for Biological Waste Treatment, Proc. 32nd Industrial Waste Conference, Purdue Univ., 1-9, 1977.

6. Brooks, A. Textile Effluent: A closer look at the Problem, Knitting International, 81, March, 81-84, 1974.

7. Parish, G.J. Textile & Tannery Wastes, Ch. 14 in Treatment of Industrial Effluents, (Eds. Callely, A.G. Foster, C.F. and Stafford, D.A.) Hodder and Stoughton, London, 1977, 378 pp.

8. Anderson, C.A. & Wood, G.F. Textile Effluents and their treatment, Textile Journal/Australia, 48, 10, 42-50, 1973.

9. Best, G.A. Water Pollution and Control, J.Soc. Dyers and Colourists, 90, 11, 389-393, 1974.

10. Wheatland, A.B. Treatment of Waste Waters from the Textile Industry, Shirley Institute pamphlet no. 92, 35-59, Manchester, 1965.

11. An Industrial Waste Guide to the Cotton Textile Industry, U. S. Dept. of Health, Education & Welfare, 1959.

12. Gardiner, D.K. and Borne, B.J. Textile Waste Waters: Treatment and Environmental Effects, J. Soc. Dyers and Colourists, 94, 8, 339-348, 1978.

13. Rhoades, J.B. Pollution Problems - Especially in Relation to the Textile Industry, J. Bradford Textile Soc., 34-38, 1975.

EPA-287 (Cin.)
(4-76)

References Continued

14. Franklin, J.S., Barnes, K.and Little, A.H. Textile Effluent Treatment with Flue Gases, International Dyer & Printer, 142, 427, 1969.

15. Little, A.H. The Treatment and Control of Bleaching and Dyeing Wastes, Wat. Pollut. Control, 68, 2, 178-189, 1969.

16. River Water Quality, The Next Stage; Review of Discharge Consent Conditions, National Water Council, London, 1977, 10 pp.

17. Personal Communication, M.R.V. Lawford, Effluent and Water Treatment Manager, Tootal Ltd., January, 1980.

18. Water Quality Review 1976, North West Water Authority, Warrington, 1977, 300 pp.

19. Annual Report, Mersey & Weaver River Authority, Warrington, 1973.

20. Ward, Ashcroft and Parkman, Feasibility Report on the Transfer of Sewage from Whaley Bridge to New Mills, Liverpool, 1972, 38 pp.

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

PB83-142364

CASE STUDY OF A POTATO CHIP PRODUCER DISCHARGING TO A SMALL MUNICIPAL TREATMENT SYSTEM

A. W. Wilson
Manager, Environmental Engineering
Reid, Crowther & Partners Limited
Sixth Floor, 220 Duncan Mill Road
Don Mills, Ontario
Canada M3B 3J5

ABSTRACT

An investigation was made of the causes of chronic upset conditions at a small municipal treatment plant receiving a large proportion of potato chip processing wastewater. The investigation encompassed a review of effluent loadings from the potato chip production process, improvement of pre-treatment facilities, and separate treatment of the caustic waste generated during cleaning of the fryers. Not all of the problems at the sewage treatment plant were due to the potato processing wastes. Periodic hydraulic surging caused by a sewage pumping station was impairing the performance of the primary treatment system. A marginal nutrient limiting condition in the secondary section of the treatment plant was identified, and an appropriate operating range for the process control parameters was recommended. The importance of collecting representative composite samples to provide an accurate reflection of the loadings on the treatment plant was noted.

INTRODUCTION

The Hostess Food Products Limited plant in Cambridge, Ontario, Canada, manufactures a variety of snack food items, including potato chips, corn and tortilla chips, cheese sticks, pretzels, popcorn and novelty sugar candy item called "poprocks". Potato chip production is by far the largest volume operation at the plant and is also the largest source of process wastewater generated at the plant. With this in mind, this paper will highlight those aspects of an investigation into the wastewater discharges relevant to Hostess potato chip production, with minimal reference to wastewater generated by the other production processes.

Wastewaters from the Hostess plant are treated at the Preston treatment plant - one of three municipal sewage treatment plants serving the city of Cambridge. The treatment plant is of the conventional activated

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

sludge type designed to treat 16,850 cubic metres per day (4.45 x 10^6 U.S. gallons per day) of domestic wastes. Average daily wastewater flow to the plant is about half of this figure.

While Hostess' process wastewaters amounted to about 20 percent of the total hydraulic loading on the treatment plant, they made up over 75 percent of the contaminant loading prior to implementation of the recommendations that evolved from the investigation.

In recent years, the treatment plant has experienced operating problems, some of which were allegedly attributable to Hostess' wastes. These problems eventually reached crisis proportions as numerous odour complaints were registered by residents living near the treatment plant coincident with severe upset conditions in the sewage treatment process.

Subsequent to this, the investigation and remedial program reported herein was launched. This paper reviews the major findings and recommendations of that program.

INVESTIGATION AT POTATO PROCESSING PLANT

The Potato Processing Operation

A sketch of a typical potato processing line at Hostess as it appeared before this investigation is presented in Figure 1.

From the storage bins, the raw potatoes are loaded into a surge hopper, following which, they enter a rod washer where dirt is washed from their outer skins. After washing, the potatoes are peeled in an abrasive peeler and pass over an inspection table where below-specification potatoes are manually culled for disposal elsewhere.

The peeled potatoes are directed to a fryer line feed hopper located at the front each line. This hopper provides a buffer capacity to absorb surges due to irregularities in either the potato peeling lines or the potato chip frying line. This feed hopper discharges to a slicer which slices the peeled raw potatoes into thin wafers. The sliced potatoes enter a washer/blancher unit in which they are washed and sometimes blanched. Following the washing/blanching step, the slices enter the fryer where they are cooked in hot vegetable oil. Upon exiting the fryer, they are given final inspection; the desired seasoning added, and they are packaged for shipment.

For every pound of potato chips produced, approximately four pounds of raw potatoes are utilized. The large discrepancy between the quantity of raw potatoes and the quantity of final product is due mainly to the evaporation of a portion of the moisture content of the potato slices during frying. The peeling, slicing, washing/blanching, and off-specification material losses account for the balance of the discrepancy.

While potato chip production fluctuates seasonally according to market demand, it is generally a two-shift operation, five days per week. The fryers are drained and cleaned with a hot caustic solution during the third shift.

Wastewater Sources

In Figure 1, it is seen that the major water-using components in the production line are the washer, the peeler, the slicer, the washer/blancher and the fryer exhaust gas scrubber. To reduce purchased water consumption, the slicer water and scrubber blowdown are discharged to the washer/blancher units.

There are three continuous-flow sources of wastewater which are discharged to the plant drains - the washer effluent, the peeler effluent, and the washer/blancher overflow. The washer effluent contains mainly grit and silt washed from the outside of the raw potatoes. The peeler discharge contains the peelings and some starch granules released from beneath the skin of the potatoes during the peeling operation. The washer/blancher overflow contains whatever oil that entered with the scrubber blowdown and has a high starch content due to the potato starch released during the slicing and washing operation.

An intermittent effluent source, indicated by the dotted line in Figure 1, is the caustic boilout from the fryer. This is a hot and highly alkaline stream consisting of some free caustic and saponified cooking oils.

In-Plant Wastewater Survey

A sampling and analytical program for each contaminated effluent source in the Hostess plant was performed. Composite samples were collected during the operation of each production line and a typical total daily process wastewater loading of about 4,540 kilograms per day (10,000 pounds per day) each of BOD_5 and Suspended Solids (S.S.) was estimated. The total wastewater flowrate was approximately 1,360 cubic metres per day (360,000 U.S. gallons per day). The contaminant breakdown for the various "wet processing" product lines was as follows:

Product Line	BOD_5 Contribution	S. S. Contribution
Potatoes	70%	83%
Corn	15%	17%
Sugar	15%	Nil
Pretzels	Nil	Nil
Totals	100%	100%

As indicated above, potato chip production was by far the largest contributor to the total effluent loadings.

During the sampling survey, it was found that the unit effluent loadings were approximately 14.5 and 16 kilograms of BOD_5 and Suspended Solids respectively per tonne of raw potatoes processed (29 and 32 lbs/ton). These loadings are within the range of normally expected effluent loadings from potato processing operations as reported in the technical literature (5) (10).

Potato Slicing and Washing/Blanching Discharges

Concern had been expressed by the Regulatory Authorities that "emulsified oil" contained in the fryer exhaust scrubber blowdown was the cause of many of the problems experienced at the municipal sewage treatment plant. The scrubber blowdown stream is normally directed to the washer/blancher where its heat content provides hot-water makeup and its oil content assists in controlling excessive foaming in these processing units. The authorities were of the opinion that the Oils and Grease content of the scrubber blowdown (which varies between about 50 and 200 mg/l) was interfering with the settling performance of the primary clarifiers at the treatment plant.

Therefore, it was decided to conduct a definitive study of the effects of the scrubber blowdown on the characteristics of the washer/blancher discharge. At the same time, the effects of blanching on the characteristics of the wastewater were also evaluated. These assessments were done on a full-scale basis using the potato chip fryer lines at the Hostess plant.

The results are summarized in Tables 1 and 2 for two separate sampling surveys. From these two Tables, it is seen that diversion of the scrubber blowdown away from the washer/blancher units had no significant effect on the settleability characteristics of the washer/blancher overflow stream.

However, blanching of the potato slices had marked effect on washer/blancher effluent quality. When the potato slices were not blanched, the washer/blancher overflow stream still had a high degree of contamination but substantially more of it was settleable by gravity sedimentation than if the potato slices were blanched. It is evident that the potato starch released during the washing operation settles quite well as long as it is not cooked by operating the washer/blancher unit at blanching temperatures.

The above data indicate that the settleability of the potato processing wastewater would be substantially greater if the potato slices were washed and blanched sequentially in two separate processing units rather than the Hostess practice of combined washing and blanching in a single unit. The Suspended Solids (mostly potato starch particles) released from the potato slices during the slicing and washing only steps would be discharged to the plant drains in the washer overflow, would settle readily in a clarifier.

Table 3 quantifies the benefits to be gained in altering the settleability characteristics of the potato chip washer/blancher overflow water by separation of the washing and blanching functions into two units. The data reported in Table 3 were estimated from the results of a third intensive sampling survey in combination with data on washer/blancher overflow rates and potato chip production rates. The data indicate that less total BOD_5 is discharged to the plant drains if the washing and blanching functions are separated than if they are combined. Furthermore, approximately half of this BOD_5 is settleable, whereas less than 20 percent is settleable if the washing and blanching functions are combined into one processing unit. For Suspended Solids, it is seen that about double the amount of Suspended Solids is generated by separating the washing and blanching functions. However, the characteristics of the solids so generated are such that over 85 percent of them are settleable, whereas only about 30 percent of the Suspended Solids generated during combined washing/blanching are settleable.

Effects of Chilling of Samples

Previous work done elsewhere by Hostess' parent company, General Foods Corporation, as well as the early sampling results of this investigation indicated that chilling of the samples had a marked effect on the Suspended Solids levels measured at the laboratory according to Standard Methods (12). Table 4 summarizes the effects of preserving the potato processing wastewater samples by means of chilling prior to laboratory analysis. After collection, all samples (chilled or not chilled) were held overnight prior to analysis.

In Table 4 it is seen that there is little effect (approximately 10 percent or less) on the BOD_5 values of the washer/blancher samples and blancher only samples. The "chilled" BOD_5 of the prewasher samples averaged about 30 percent less than the "not chilled" BOD_5 of the same samples. As heating during blanching will have some sterilizing effect, it is reasonable to expect that the microbial populations in the pre-washer samples would be far greater than those of either the blancher samples or the washer/blancher samples. It is hypothesized, therefore, that the difference in BOD_5 values between the "chilled" and the "not chilled" prewasher samples is due to anaerobic bacterial activity causing a solubilization of a portion of the starch in the "not chilled" samples with a resulting higher BOD_5.

It is evident from Table 4 that there is a marked increase in Suspended Solids caused by chilling of the washer/blancher samples. It is hypothesized that this is due to a coagulation of a portion of the colloidal cooked starch content of the "chilled" sample and that these coagulated solids are then retained on the filter paper during the Suspended Solids test. Conversely, if the sample were "not chilled", the collodial solids would not coagulate and would pass through the filter paper.

The "chilled" prewasher samples had a Suspended Solids level about 11 percent higher than the "not chilled" prewasher samples. It is hypothesized that a portion of the uncooked starch granules in the "not chilled" prewasher samples was solubilized by anaerobic activity as mentioned earlier thereby resulting in a lower Suspended Solids level and a higher BOD_5 level than in the "chilled" prewasher samples.

The "chilled" blancher samples exhibited a Suspended Solids level about 20 percent higher than the "not chilled" blancher samples. This is likely due to the coagulation of a portion of the colloidal cooked starch content of the samples upon chilling as discussed above.

Table 4 indicates that the BOD_5 level of potato processing wastewater samples will increase upon standing if "not chilled". Table 4 also indicates that "chilling" of the samples will cause an erroneously high Suspended Solids level. Therefore, it is also important to note the advantage of split sampling - "chilling" a portion of the effluent sample for BOD_5 analysis and "not chilling" a portion of the sample for Suspended Solids analysis. Furthermore, it is also important that the samples be analyzed as soon as possible after collection.

Caustic Boil-Out Treatment

On the night shift each week-night, two potato chip fryers are cleaned using a hot caustic solution. The resulting alkaline discharge to the sewer is termed the "caustic boil-out". It is discharged over a relatively short period of time (i.e. the time it takes to pump out the fryer) and therefore constitutes a slug discharge from the plant occurring during the early morning hours.

Over ten different samples of caustic boil-out were evaluated and in general, no two samples exhibited identical characteristics. Some of the variations noted were as follows:

- Some separated into layers on standing for less than a day; others did not separate at all even after standing for a month.
- Some formed a thick and relatively hard congealed layer on top; others formed only a soft layer.
- Some formed a foamy layer on top; others did not.
- Some samples turned completely into a gel after standing for two to three days; others did not.

In addition to the above, BOD_5 determinations on the caustic boil-out were very high and varied from about 10,000 mg/l to over 60,000 mg/l. There was also some evidence of a toxic inhibition caused by some constituent of the caustic boil-out as higher BOD_5 values were observed with larger dilutions in the BOD_5 test. This toxicity is likely due to the soap content of the caustic boil-out created as a result of a saponification reaction between the hot caustic solution and any residual cooking oil it contacts while circulating through the fryer. Aside from any congealed greasy substance that might have formed, all samples showed very little evidence of Suspended Solids contamination.

As the caustic boil-out is a very strong waste and is discharged as a slug, it was suspected as one possible cause of the upset conditions at the municipal treatment plant. Therefore, it was recommended that it be segregated from the other Hostess wastewaters for separate treatment.

Laboratory bench-scale studies on several samples showed that physical-chemical treatment using a combination of lime and/or calcium chloride and/or sulphuric acid could break emulsified oils and precipitate soluble soaps from solution. The precipitation was filterable and a clear filtrate resulted.

Due to the variations in the characteristics among the several samples tested, the full-scale caustic boil-out treatment system was designed to include the following processing steps:

- Retention tanks of sufficient capacity to hold at least one day's production of caustic boil-out for one week to allow it to cool and to permit separation and skimming of congealed material.
- Chemical addition, mixing, and decanting facilities on the holding tanks to allow precipitation of the soluble soaps by lime or other suitable chemical.
- A plate-and-frame filter press to filter the precipitated materials and generate a filter cake for landfill disposal, and to pass the filtrate to the plant drains over an extended period of time rather than in one slug.

Table 5 shows that the full-scale caustic boil-out treatment system is capable of better than 97 percent BOD_5 removal and 99 percent Oils and Grease removal. Chemical requirements are approximately 3.3 kilograms of Calcium Chloride and 1.7 kilograms of Hydrated Lime per cubic metre of caustic boil-out treated (27.5 and 14.2 pounds per 1000 U.S. gallons respectively). This is equivalent to an approximate chemical cost of $100 per tonne of caustic boil-out treated ($3.80 per 1000 U.S. gallons).

Hostess' Pre-Treatment System

When the chronic upset conditions at the municipal treatment plant reached crisis proportions, a number of interim measures were instituted by Hostess in an attempt to alleviate the problem. One such measure was the installation of a modified truck trailer body to act as a wastewater settling basin at the Hostess plant to reduce effluent loadings to the municipal sewer system.

Subsequently, it was found that this settling basin was removing about 900 kilograms per day (2000 pounds per day) of Suspended Solids from the plant effluent. As it was relatively economical to install and operate, it was decided to upgrade the truck settling basin concept into a permanent pre-treatment system as part of the investigative and remedial program described in this paper.

EPA-287 (Cin.)
(4-76)

Accordingly, a number of recommendations were made to improve the pretreatment system and, at present, the system incorporates the following steps as schematically illustrated in Figure 2:

- All process wastewaters except the caustic boil-out are directed to an in-plant pumping station. The pumping station consists of a large sump and two self-priming pumps. A float switch activiting a high level alarm is located in the sump to warn of pump failure and an impending overflow discharge to the municipal sewer system.
- The wastewater is pumped to two Hydrasieve screening units having screen openings of 1 millimetre (0.04 inches). Solids coarser than this (mainly peels, etc.) are separated from the main stream and are discharged down a chute into tote bins for ultimate disposal to a feedlot operation.
- After screening, the wastewater passes through two settling basins operating in parallel, which together provide a theoretical retention time of about 40 minutes. Heavy solids separate by gravity to the bottom of the basins. In addition, a pair of baffles in each basin retains any floating oils and greases. Multiple weir plates along the width of each end of the settling basins provide adequate inflow and overflow distribution patterns.
- The overflow from the settling basins passes through a Parshall Flume to monitor the flowrate. A flow-proportional automatic sampling device is also provided to sample the discharge from the settling basins.

When a basin fills with settled material, it is hauled away and dumped at a feedlot operation. A third truck trailer body is available to replace the trailer being dumped. Each basin is dumped on alternate days, usually early in the morning before start-up of the first shift.

INVESTIGATIONS AT MUNICIPAL TREATMENT PLANT

Description of Preston Treatment Plant

A schematic diagram illustrating the wastewater sources to, and the various processing operations of the Preston treatment plant is presented in Figure 3. The nominal hydraulic design capacity of the plant is 16,850 cubic metres per day (4.45×10^6 U.S. gpd). The nominal design BOD_5 and Suspended Solids capacity is 7940 kilograms per day each (17,500 pounds per day each). It is designed and built as a conventional activiated sludge plant for the treatment of municipal wastes.

Wastewater arrives at the plant by means of four gravity sewers. Each sewer transports domestic waste; however the Bishop Street sewer also conveys the major portion of the industrial waste loadings on the Preston plant. It is worth noting that wastewater from the large Dover Street Pumping Station is pumped directly to the plant through about 1200 metres (4000 feet) of 406 millimetre (16 inch) forcemain followed by 460 metres (1500 feet) of gravity sewer with no lateral connections.

The primary treatment system at the Preston plant consists of trash racks, grit removal, shredding and gravity sedimentation. Grit removal is accomplished in a mechanically-raked "square" detritor and a barminutor serves to shred the larger particles in the wastewater stream. Following shredding, the wastewater enters primary clarifiers. There are four primary clarifiers each 15.2 metres (50 feet) in diameter.

The primary effluent enters the aeration tanks where dissolved oxygen is supplied to the micro-organisms by a mechanical aeration system. The Preston plant has two aeration tanks in parallel. Each tank has a aeration energy input of 93.3 kilowatts (125 HP) provided by five surface mechanical aerators.

An iron solution is metered into the front end of the aeration tanks to precipitate soluble phosphorus from the wastewater stream.

The aeration tanks discharge to four secondary clarifiers each 15.2 metres (50 feet) in diameter. Excess activated sludge flow is "wasted" to the solids handling system via a splitter box to the primary clarifiers.

The raw sludge withdrawn from the bottom of the primary clarifiers is pumped to the sludge digesters. The sludge digestion system consists of two tanks, each 15.2 metres (50 feet) in diameter by 11.6 metres (38 feet) liquid depth providing a nominal retention volume of 4520 cubic metres (159,600 cubic feet). The primary digester is heated to 35°C (95°F).

Digester gas is generated as a by-product of the digestion process and is used in a heating system to heat the digester tank contents. Excess digester gas is flared to atmosphere.

Historical Data

Plant operating records over a five-year period prior to the crisis upset conditions were examined. The data indicated that the plant was operating at about half of stated design capacity for both BOD_5 and Suspended Solids as well as flow.

Despite this, when the severe upset conditions occurred over a three-month summer period, there was no Suspended Solids removal and very little BOD_5 removal in the primary clarifiers. Depending upon the severity of the situation at any time, the secondary section of the plant would be overloaded as well. These upset conditions coincided with heavy scum accumulations on the primary clarifiers and numberous odour complaints from nearby residents.

Preston Treatment Plant Loadings

In order to confirm the loading data in the plant's operating records and to establish the diurnal variations in wastewater contaminant loadings, a 24-hour sampling program was implemented at the Preston plant.

The daily BOD_5 and Suspended Solids loadings were measured to be 6620 and 5810 kilograms per day respectively (14,600 and 12,800 pounds per day respectively). These are considerably greater than the average daily BOD_5 and Suspended Solids loadings of about 4260 and 3450 kilograms per day respectively (9,400 and 7,800 pounds per day respectively) indicated on the daily plant record sheets for that period.

While it is possible that the loadings may have been unusually higher than average during the sampling survey, it is more likely that the daily plant records underestimated the actual situation. The plant data were based on 8-hour composite sampling of raw wastewater entering the plant during the day shift only. As Hostess potato processing operations commence at 0700 hours and there is a 3-hour time of travel in the Bishop Street sewer, the first portion of the 3-hour composite sample would be mostly the relatively "weak" domestic wastes. Hostess potato processing, which represents about 70 to 80 percent of the total Hostess loading, continues for two shifts until 2300 hours. Clean-up operations on the potato processing lines often occur during the latter part of the second shift. Therefore 8-hour composite sampling of raw wastes at the Preston plant would be non-representative of the actual situation.

Table 6 summarizes the hydraulic, organic and solids loadings on the Preston treatment plant. It is interesting to note that, while the Hostess discharges represented less than 20 percent of the hydraulic load on the Preston plant, they accounted for in excess of 75 percent of the BOD_5 and Suspended Solids loadings.

On examining the diurnal variations, it appeared that high BOD_5 and Suspended Solids concentrations occurred in the raw wastewater in the period between 0300 and 0500 hours. This corresponded to the time that the caustic boil-out discharges were expected to reach the plant. This was verified by visual inspection of these samples (they appeared milky-white in colour) and the fact that they had elevated pH level.

In view of the above, it was recommended that an automatic sampling device be installed permanently at the Preston treatment plant to give a more accurate picture of the plant loadings. The sampler should have the capabilities of collecting discrete as well as composite samples around-the-clock.

Hydraulic Surging

Inspection of the Preston plant's flowmeter charts showed that the plant was subjected to severe hydraulic surgings. The plant operating personnel confirmed this, but the specific cause of the surges was not known for certain. The flowmeter charts indicated a surging pattern as follows:

> A hydraulic surge to a flowrate often in excess of 20440 cubic metres per day (5.4 million Imperial gallons per day) occurring approximately each hour during the daytime and every two to three hours at night. This surge started abruptly and ended abruptly and had a duration of about 5 minutes.

After reviewing a drawing of the city's sewage collection system and making a visual inspection of the flow patterns in the various sewer manholes leading to the plant, it was determined that the surge was due to the on-off operation of the Dover Street Pumping Station. Inspection of the pumping station indicated that there was considerable excess capacity built into the station for future expansion of the municipality. The pumps were far larger than required for current flows. While this would be useful in the long term, the nominal hydraulic design capacity of the present primary treatment system was exceeded by about 10 to 15 percent when this pumping station operated. Such an excess usually would not result in serious upset problems; however, with the unique combination of factors that occurred at the Preston plant, the surging served to aggravate an already potentially troublesome situation. The various factors were:

- The occurence of Oils and Grease accummulations from a possible spill at Hostess and/or caustic boil-out gel accummulations on the primary clarifiers.
- The existence of readily bicdegradeable but poorly-settling gelatinized starch waste resulting from the combined washing/ blanching operations on the Hostess potato chip lines.
- The wastewater entering the plant during these surges had different characteristics than that entering the plant at most other times with the result that undesirable density currents would be created leading to unstable flow patterns in the primary clarifiers.
- The average hydraulic loading on the Preston treatment plant is about half of the nominal design capicity. Therefore surges due to the Dover Street Pumping Station resulted in an instantaneous peaking factor of about 3:1. Such conditions are unacceptable for good primary clarifier performance which is dependent upon quiescent settling conditions.

It was recommended that the pumps in the Dover Street Pumping Station be changed to pump at a lower rate over a longer period of time during each pumping cycle.

Organic Loading on Preston Treatment Plant Secondary Section

The efficient performance of any biological waste treatment system depends upon an optimal combination of several design and operating variables, all of which are inter-related to some degree in a complex physical, chemical and biochemical system. In order to simplify the system, several parameters are used as a guide to assist the process engineer in designing the treatment plant, and the operator in controlling the process once it is in operation.

One of these is called the "Food-to-Micro-organism Ratio " (F:M) and is a measure of the organic strength of the wastewater (expressed daily mass loading of BOD_5) in relation to the amount of activated sludge microbial mass that is available in the secondary treatment system (expressed as mass of Volatile Suspended Solids in the aeration tanks) to consume it.

During the sampling period, the F:M ration was calculated to be 0.68 days^{-1}. This figure is somewhat high and is outside of the traditional "acceptable" F:M range of 0.2 to 0.5 days^{-1} for a conventional activated sludge plant. For this particular plant treating this particular wastewater having an unusually high carbohydrate content, the recommended operating range is as follows:

F:M	MLSS
0.24 days^{-1}	4000 mg/l
0.32 days^{-1}	3000 mg/l

The above assumes an 85 percent volatile content in the Mixed Liquor Suspended Solids.

The operating staff at the plant have experienced problems in maintaining a high biomass concentration in the aeration tanks, and thereby a high F:M ratio results. This is due to poor settleability of the biomass and could be caused by many factors. Some possibilities are as follows:

- Insufficient nutrient concentrations in the primary effluent for the promotion of a healthy activated sludge biomass (see below). This is often the case with potato processing wastewater.
- Insufficient aeration retention time for the micro-organisms to digest the high carbohydrate content of this particular wastewater and form a well-flocculated,rapidly-settleable biomass.
- Toxicity of the saponified oils discharged in the Hostess caustic boil-out discharges.
- Toxicity of heavy metals discharged from other industrial sources. In the past, several process upsets in the secondary section of the plant have been attributed to heavy metal discharges from other industries

Nutrient Availability in Preston Treatment Plant Secondary Section

Nitrogen and Phosphorus nutrients must be present in the primary effluent in sufficient amount and in an appropriate chemical form such that the healthy growth of the biomass at the expense of the organic contaminants in the wastewater is not impaired by a nutrient-limiting condition. Typically a BOD_5:N:P ratio of 100:5:1 is considered acceptable for activated sludge treatment.

Nitrogen and Phosphorus determinations were made on composite samples of primary effluent collected during the sampling survey. It was found that there was sufficient Nitrogen in the primary effluent; however the adequacy of the Phosphorus content was questionable. This marginal situation was further aggravated by the addition of Phosphorus-precipitating chemicals at the head end of the aeration tanks causing insoluble phosphate compounds to form which rendered the Phosphorus unavailable to the biomass.

In support of this concept, an examination of historical plant data on the settleability of the Mixed Liquor Suspended Solids was made. The interval covered included both before and after the changeover from Ferric Chloride addition at the outlet of the aeration tanks to a Ferrous/Ferric solution addition at the entrance of the aeration tanks. The average monthly data are presented in Table 7.

While it is recognized that analysis of the historical data in this fashion overlooks many other factors occurring simultaneously, nevertheless an obvious trend is evident - that the settleability of the Mixed Liquor deteriorated after the replacement of Ferric salts by Ferrous/Ferric salts and the change in dosing point of the chemical.

Further evidence of a Phosphorus-limiting conditions was found by measuring the Phosphorus content of the Mixed Liquor biomass in the secondary treatment section of the plant. The average Total Phosphorus content of the Mixed Liquor Suspended Solids in the aeration tanks during the sampling survey was 5.75 mg/l. The average Mixed Liquor Volatile Suspended Solids concentration was 1420 mg/l. Therefore, the fraction of Phosphorus in the MLVSS is 0.0041. A typical literature value (9) for activated sludge is 0.0116. Therefore, the Preston plant's Mixed Liquor appears to be Phosphorus deficient.

It was recommended, therefore, that a return to Ferric salts for precipitation of Phosphorus be made and that the dosing point be changed back to the aeration tank overflow in order to minimize the possibility of a limiting Phosphorus nutrient condition developing in the secondary section of the treatment plant.

CONCLUSIONS AND RECOMMENDATIONS

Regarding the Potato Chip Processing Plant

The following conclusions and recommendations are made relevant to the potato chip processing plant:

(1) If blanching of the potato chip is necessary, then a pre-washing step prior to blanching will improve substantially the settleability of the potato processing wastewaters.

(2) Conclusion (1) above has important implications for either the design or the operation of treatment facilities for potato processing waste. A primary treatment system will be much more effective on treating wastewater from separate washing and blanching facilities than from a combined washing/blanching unit. Furthermore, if secondary biological treatment is required, it can be a smaller and less expensive system if the washing and blanching functions are separated than if they are combined. If the washing and blanching functions are combined, there would be a much higher BOD$_5$ load pass through the primary system and into the secondary system.

(3) Either for determining the loading on a treatment system for potato processing wastes, or for estimating surcharge penalties for discharge of the wastes to a municipal sewer system, it is important to collect split samples of the wastewater stream. One sample should be chilled immediately for BOD$_5$ analysis, and the other should be maintained at

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

room temperature for Suspended Solids analysis. Furthermore, the samples should be analysed as soon after the sampling as possible to prevent microbial activity from causing a deterioration of the sample.

(4) The caustic boil-out discharge resulting from fryer cleaning operations represents a "slug" discharge of a very high strength waste containing appreciable quantities of emulsified and saponified cooking oils. This discharge could have a significant negative impact on the operation of smaller size treatment facilities where the dilution afforded by wastewaters from other sources is not large. A treatment process consisting of retention tanks to permit separation and skimming of congealed materials; chemical addition, blending, and decanting facilities for precipitation of soluble soaps; and a filter press to filter the precipitated materials before discharging the filtrate to the sewer, will substantially reduce the strength of the caustic boil-out waste stream.

(5) A "quick and dirty" but economically effective wastewater pre-treatment system has been designed and installed by Hostess for all process wastewaters excluding the caustic boil-out. The system consists of screening followed by gravity separation of settleable and floatable materials into appropriately modified dumptruck trailers. Each trailer is taken off-line on alternate days and the accumulated solids therein are hauled to a feedlot and dumped.

Regarding the Municipal Treatment Plant

Based upon the results of this investigation, the following points should be given consideration in situations where a large wet processing industry located in a relatively small community is discharging wastewater to the sewer system for subsequent treatment at the municipality's sewage treatment plant:

(1) Whereas the treatment plant may only be staffed on one shift and the industry may be in production over two or more shifts each day, an automated 24-hour sampling device should be used to collect resentative samples of the combined wastewater for an accurate determination of the loadings on the treatment plant.

(2) All reasonable measures should be taken to avoid situations which by themselves may not be of much significance (e.g. hydraulic surging), but when in combination with other circumstances, may serve to aggravate a chronic but marginally tolerable problem to crisis proportions.

(3) The nutrient balance in the combined wastewater must be adequate for effective biological treatment.

(4) Proper operating conditions (as defined by the F:M ratio or other acceptable operating parameter) consistent with effective biodegradation of the particular wastewater stream undergoing treatment should be maintained in the biological treatment section.

(5) When a major portion of the loading to the treatment plant originates from an industrial source(s), the design of the treatment plant must accommodate the treatability characteristics of the industrial waste(s) involved.

(6) And last but not least, an effective mechanism of communication should be established between the responsible industrial staff, the treatment plant operating staff, municipal officials, and the Regulatory Authorities. If this is done, a confrontation atmosphere can be avoided whenever problems arise, and all concerned can set about resolving the difficulties.

OUTCOME

With the implementation of the following measures at the Hostess plant:

- Separation of washing and blanching to alter the settleability characteristics of the potato processing wastewater,
- Upgrading of Hostess' pre-treatment facilities to improve the degree of treatment given to the wastes before discharge to the municipal sewer system,
- Implementation of a caustic boil-out treatment system,
- Improved employee awareness and in-plant housekeeping to avoid accidental spills, unnecessary dumping, etc.

a reduction in contaminant loadings discharged to the municipal sewer system of about 50 percent has been effected. In addition to resolving the process upset and odour problems at the Preston treatment plant, there has been a 37 percent reduction in Hostess' sewer surcharge payments to the municipality despite an 18 percent increase in the sewer surcharge rate.

ACKNOWLEDGEMENTS

The co-operation and assistance of representatives of the following organizations during the conduct of the investigation are gratefully appreciated:

- City of Cambridge
- Regional Municipality of Waterloo
- Ontario Ministry of Environment
- Hostess Food Products Limited

REFERENCES

(1) Atkins, P.F., and Sproul, O.J., "Feasibility of Biological Treatment of Potato Processing Wastes", Journal Water Pollution Control Federation, 38, 1287 (1966).

(2) Cansfield, P.E., and Gallop, R.A., "Conservation, Reclamation and Re-Use of Solids and Water in Potato Processing", A paper presented at the 19th Annual Ontario Industrial Waste Conference, (1970).

(3) French, The R.T. Company, "Aerobic Secondary Treatment of Potato Processing Wastes", NTIS Publication No. PB200623, December, 1970.

EPA-287 (Cin.)
(4-76)

(4) Grames, L.M., and Jueneman, R.W., "Primary Treatment of Potato Processing Wastes with Byproduct Feed Recovery", Journal Water Pollution Control Federation, *41*, 1358 (1969).

(5) Guttormsen, K., and Carlson, D.A., "Current Practice in Potato Processing Waste Treatment", NTIS Publication No. PB189232, October, 1969.

(6) Landine, R.C., and Dean, J.R., "Waste Treatment and Solids Recovery System for a French Fried Potato Processing Plant", A paper presented at the 19th Annual Ontario Industrial Waste Conference, (1972).

(7) McKinney, R.E., *Microbiology for Sanitary Engineers*, McGraw-Hill, New York, 1962.

(8) Metcalf & Eddy, Inc., *Wastewater Engineering - Collection, Treatment, Disposal*, McGraw-Hill, New York, 1972.

(9) Rich, L.G., *Unit Processes of Sanitary Engineering*, Johy Wiley & Sons, Inc., New York, 1963.

(10) Stephenson, J.P., and Guo, P.H.M., "State-of-the-Art Review of Processes for Treatment and Reuse of Potato Wastes", Environmental Protection Service, Environment Canada, Report No. EPS 3-WP-77-7, March 1977.

(11) United States Environment Protection Agency, "Pollution Abatement in the Fruit and Vegetable Industry", U.S. E.P.A. Publication No. EPA-625/3-77-0007, July 1977.

(12) Water Pollution Control Federation, American Water Works Association, American Public Health Association, *Standard Methods for the Examination of Water and Wastewater*, 14th Edition, 1976.

TABLE 1 EFFECTS OF BLANCHING AND SCRUBBER DIVERSION ON WASHER/BLANCHER OVERFLOW SETTLEABILITY SAMPLING SURVEY NUMBER 1

Potato Chip Fryer No.	Blanching?	Scrubber Discharge?	Settleable BOD_5 Fraction	Settleable S.S. Fraction
1	Yes	To Blancher	10%	85%
2	Yes	Diverted	13%	86%
3 (a.m)	No	To Blancher	55%	98%
3 (p.m.)	No	Diverted	65%	99%
4	No	To Blancher	70%	95%

Note difference in settleabilities between blanching (#1 and #2) and not blanching (#3 and #4). Scrubber diversion away from the washer/blancher units does not appear to have substantial impact on the settleability of the washer/blancher overflow.

Average settleable BOD_5 fraction with blanching = 11.5%

Average settleable BOD_5 fraction without blanching = 63%

Average settleable S.S. fraction with blanching = 85.5%

Average settleable S.S. fraction without blanching = 97%

TABLE 2

EFFECTS OF BLANCHING AND SCRUBBER DIVERSION ON WASHER/BLANCHER OVERFLOW SETTLEABILITY SAMPLING SURVEY NUMBER 2

Potato Chip Fryer No.	Blanching?	Scrubber Discharge?	Settleable BOD_5 Fraction	Settleable S.S. Fraction
1	Yes	To Blancher	17%	72%
2	Yes	Diverted	13%	80%
3 (a.m.)	No	To Blancher	42%	95%
3 (p.m.)	No	Diverted	69%	96%
4	No	To Blancher	60%	96%
5	Yes	Diverted	7%	81%

Note difference in settleabilities between blanching (#1, #2 and #5) and not blanching (#3 and #4). Scrubber diversion away from the washer/blancher units does not appear to have substantial impact on the settleability of the washer/blancher overflow.

Average settleable BOD_5 fraction with blanching = 12%

Average settleable BOD_5 fraction without blanching = 57%

Average settleable S.S. fraction with blanching = 78%

Average settleable S. S. fraction without blanching = 96%

EPA-287 (Cin.) (4-76)

TABLE 3 ESTIMATED EFFLUENT LOADINGS FOR COMBINED AND SEPARATE WASHING AND BLANCHING

	BOD_5 Loading (kg/tonne Product)		S.S. Loading (kg/tonne Product)	
Item	Sample As Is	After 30 Min. Ideal Settling	Sample As Is	After 30 Min. Ideal Settling
Combined Washing/ Blanching	45	38	13	9
Separate Washing & Blanching	19	10	25	4

The BOD_5 values above indicate that there is considerably less BOD_5 discharged per unit of production both before and after ideal settling if the washing and blanching functions are separated than if they are combined.

The Suspended Solids values above indicate that, although there is more Suspended Solids generated per unit of production by separation of the washing and blanching functions, there is considerably less Suspended Solids discharged after ideal settling if the washing and blanching functions are separated than if they are combined.

EPA-287 (Cin.)
(4-76)

TABLE 4 SUMMARY OF EFFECT ON CHILLING SAMPLES ON MEASURED BOD_5 & SUSPENDED SOLIDS ANALYSES

Item	Ratio of "Chilled" to "Not Chilled" Sample Analysis			
	BOD_5 Ratio $\frac{\text{Chilled}}{\text{Not Chilled}}$		S.S. Ratio $\frac{\text{Chilled}}{\text{Not Chilled}}$	
	Mean	Range	Mean	Range
Washer/Blancher Samples	0.89	0.81 to 1.01	2.63	2.07 to 2.91
Prewasher Samples	0.68	0.46 to 0.83	1.11	0.76 to 1.30
Blancher	0.93	0.60 to 1.15	1.50	1.01 to 1.89

TABLE 5 RESULTS OF FULL SCALE TREATMENT OF CAUSTIC BOIL-OUT DISCHARGES

Item	BOD_5 Conc'n (mg/l)		Oils & Grease Conc'n (mg/l)	
	Before Treatment	After Treatment	Before Treatment	After Treatment
Test No. 1	59,800	1,890	26,000	88
Test No. 2	26,400	970	12,200	22

EPA-287 (Cin.)
(4-75)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

TABLE 6 SUMMARY OF LOADING CONDITIONS ON THE PRESTON TREATMENT PLANT

Item	Nominal Design	From Plant Data		Probable* Situation	
		Avg. Loading	% of Stated Design	Avg. Loading	% of Stated Design
Flow (m^3/day)	16850	7680	46	7680	46
BOD_5 (kg/day)	7940	3970	50	5960	75
S.S. (kg/day)	7940	4290	54	5960	75

* Assumes average Hostess discharges of approximately 4260 lb/day each of BOD_5 and S.S. (dependent upon production levels) plus sewered population of 18,500 each discharging 0.09 kg/day BOD_5 and 0.09 kg/day S.S.

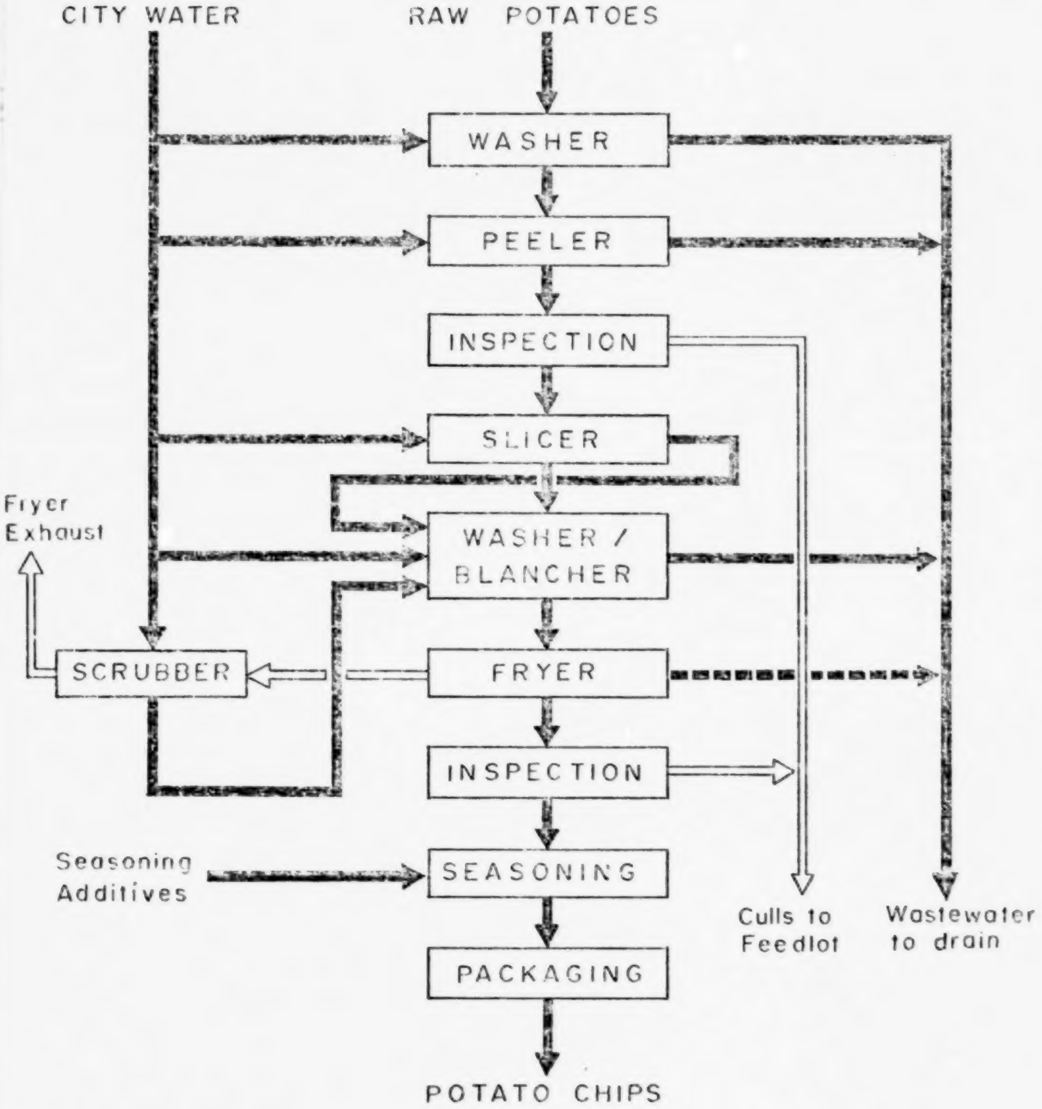
Table 7 SETTLEABILITY OF PRESTON TREATMENT PLANT MIXED LIQUOR AS A FUNCTION OF PHOSPHORUS-PRECIPITATING CHEMICAL ADDITION

Year	Phosphorus-Precipitating Chemical Used	Point of Chemical Addition	Settled MLSS Volume* After 30 Min. Settling
1	Ferric Sol'n	Aeration Output	445 ml
2	Ferric Sol'n	Aeration Output	380 ml
3 (Jan-April)	Ferric Sol'n	Aeration Output	410 ml
3 (April-Dec)	Ferrous/Ferric Sol'n	Aeration Input	665 ml
4	Ferrous/Ferric Sol'n	Aeration Input	730 ml
5	Ferrous/Ferric Sol'n	Aeration Input	755 ml

* These figures represent annual average values recorded in the plant performance records. Data covering those periods when washout of the Mixed Liquor Suspended Solids (MLSS) occured were not included in these averages. The washouts were often attributed to heavy metal contamination of the raw wastewater.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

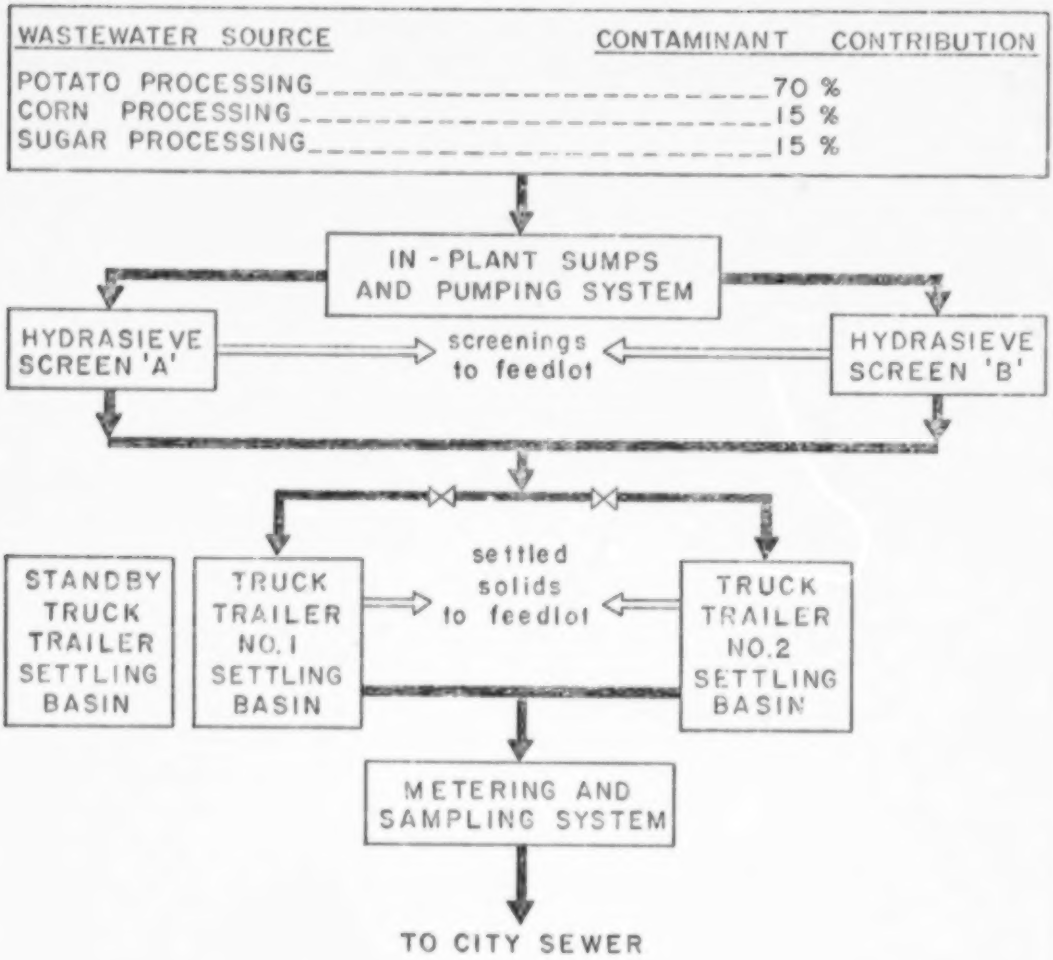

CITY WATER
RAW POTATOES
WASHER
PEELER
INSPECTION
SLICER
Fryer Exhaust
WASHER / BLANCHER
SCRUBBER
FRYER
INSPECTION
Seasoning Additives
SEASONING
PACKAGING
Culls to Feedlot
Wastewater to drain
POTATO CHIPS

POTATO CHIP PRODUCTION

FIGURE 1

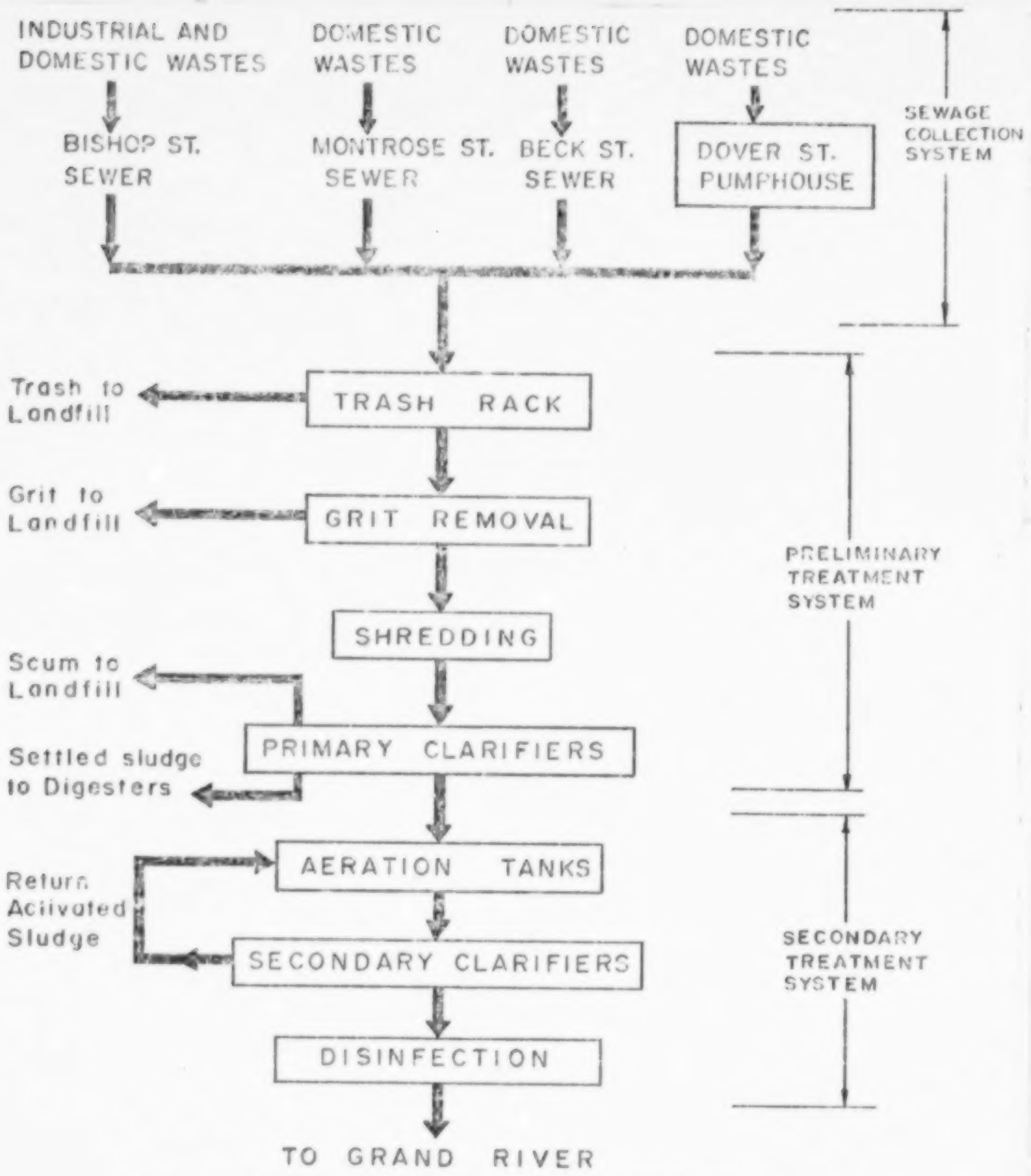
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)


WASTEWATER SOURCE
CONTAMINANT CONTRIBUTION
POTATO PROCESSING 70 %
CORN PROCESSING 15 %
SUGAR PROCESSING 15 %
IN - PLANT SUMPS AND PUMPING SYSTEM
HYDRASIEVE SCREEN 'A'
screenings to feedlot
HYDRASIEVE SCREEN 'B'
STANDBY TRUCK TRAILER SETTLING BASIN
TRUCK TRAILER NO. 1 SETTLING BASIN
settled solids to feedlot
TRUCK TRAILER NO. 2 SETTLING BASIN
METERING AND SAMPLING SYSTEM
TO CITY SEWER

HOSTESS PRE - TREATMENT SYSTEM

FIGURE 2


INDUSTRIAL AND DOMESTIC WASTES
DOMESTIC WASTES
DOMESTIC WASTES
DOMESTIC WASTES
BISHOP ST. SEWER
MONTROSE ST. SEWER
BECK ST. SEWER
DOVER ST. PUMPHOUSE
SEWAGE COLLECTION SYSTEM
Trash to Landfill
TRASH RACK
Grit to Landfill
GRIT REMOVAL
SHREDDING
PRELIMINARY TREATMENT SYSTEM
Scum to Landfill
PRIMARY CLARIFIERS
Settled sludge to Digesters
AERATION TANKS
Return Activated Sludge
SECONDARY CLARIFIERS
SECONDARY TREATMENT SYSTEM
DISINFECTION
TO GRAND RIVER

PRESTON SEWAGE TREATMENT SYSTEM

FIGURE 3

PB83-142372

JOINT TREATMENT DESIGN AND OPERATION PROBLEMS WITH A FINE PAPER MANUFACTURING WASTEWATER

J. D. Lowry
Assistant Professor of Civil Engineering
451 Aubert Hall
Civil Engineering Department
University of Maine
Orono, ME. 04473

ABSTRACT

The paper describes the efforts of the author, who was retained as an outside consultant, to evaluate and provide solutions to process problems encountered in a joint treatment facility located in Brewer, Maine. The 3.0 MGD facility receives wastewater from the city (10,000 population) and industry (fine paper making), and has been plagued with operation problems since its startup in 1976.

The objective of the paper is to discuss:

1) the technical aspects of the operation problems, with respect to design inadequacies and process operation, 2) the technical solutions to the problems, which involved a field research effort, and 3) the interactions between the city, industry, design consultant, state government, and EPA, with emphasis on how each influenced the implementation of the technical solutions.

The work described in the paper is relevant to joint treatment design and operation for two reasons. First, the Brewer, Maine facility is unique from a technical standpoint because the problem industrial wastewater loading is at a level that allowed some clear cause-effect relationships to be discerned. These included typical ones involving nitrogen and phosphorus, as well as other wastewater nutritional problems of a more unusual nature. Investigations led to some potentially meaningful data that may be applicable to facilities experiencing problems with similar wastewaters. Secondly, the Brewer facility is quite representative of the predicament small cities can find themselves in when they accept the wastewater of a comparatively large industry.

INTRODUCTION

For a variety of reasons, many municipal wastewater treatment facilities throughout the country are not meeting their prescribed effluent discharge standards (1,2). Some of these plants have experienced difficulties attributable to significant industrial wastewater loading and, in particular, joint treatment facilities are especially prone to problems caused by industrial wastewaters. Proper process design and operation is always critical to the successful performance of any treatment facility, but is usually more difficult to achieve in joint treatment applications. This paper describes the design and operation problems encountered by the author at a joint treatment facility in Brewer, ME., and details the various solution measures that have been implemented by the city and industry.

The Brewer wastewater treatment plant is a typical secondary design employing the activated sludge process. The process flow schematic is illustrated in Figure 1 and the basic design data are given in Table 1. The facility was designed for the combined treatment of wastewater from the municipality and Eastern Fine Paper Company. At the present time, the mill contributes approximately 40% of the total average flow in the form of wastewater generated from three paper machines that manufacture various grades and colors of fine paper.

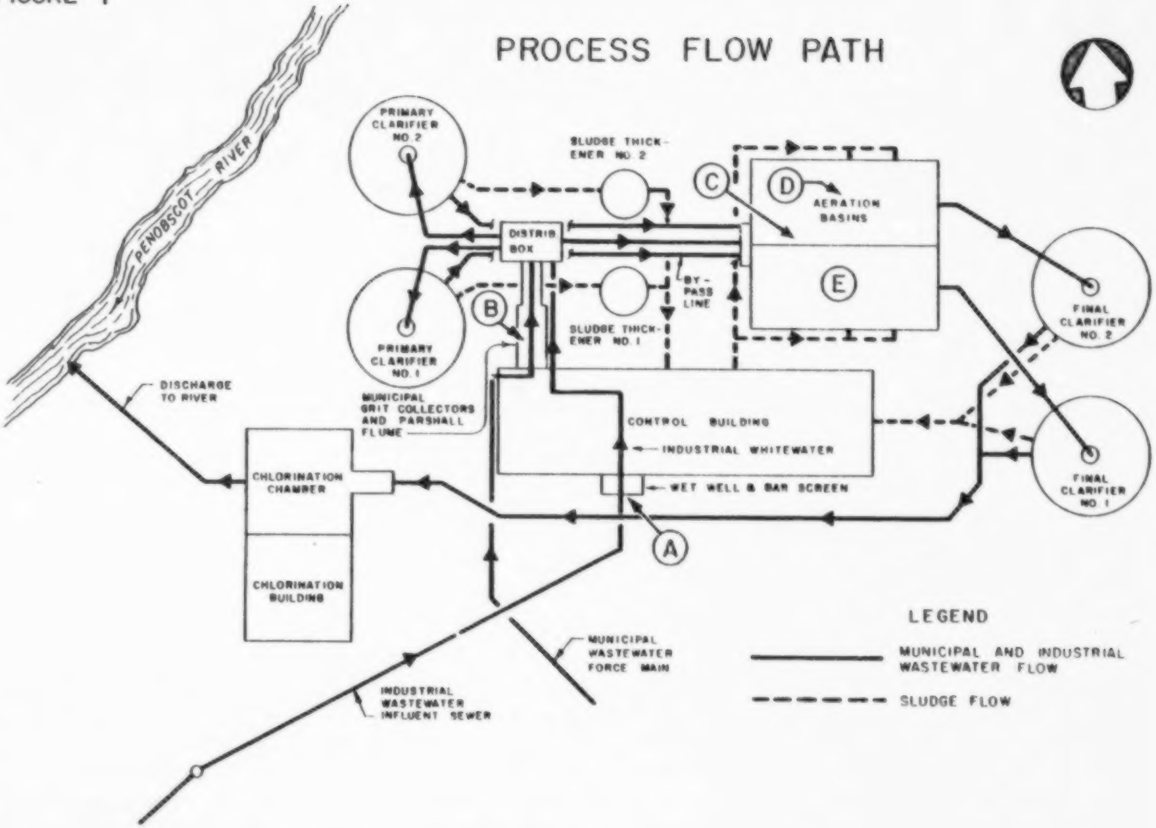
TABLE 1. BASIC DESIGN DATA

Design Flow		
	Combined	3.03 MGD
	City	1.95 "
	Mill	1.08 "
Present Flow		
	Combined	2.50 MGD
	City	1.50 "
	Mill	1.00 "
BOD$_5$	Combined	265 mg/L 6700 lb/d
SS	Combined	376 mg/L 9500 lb/d
Aeration Time, Design		7.2 hr

The activated sludge system can be operated with one or two aeration basins in service, and with one or two sedimentation basins in either case. If two aeration basins are used with two sedimentation basins, either combined or separate return sludge systems can be utilized. If the return sludge lines are kept separate, the operation becomes two parallel activated sludge systems that receive a portion of the same combined wastewater flow. This has been the mode of operation, with an intended 50:50 split of wastewater to each aeration basin-sedimentation tank combination. It is not possible to treat the Brewer and Eastern wastewaters separately due to the common aeration influent feed channel.

FIGURE I

PROCESS FLOW PATH


PENOBSCOT RIVER
PRIMARY CLARIFIER NO. 2
PRIMARY CLARIFIER NO. 1
SLUDGE THICK-ENER NO. 2
SLUDGE THICK-ENER NO. 1
DISTRIB BOX
BY-PASS LINE
AERATION BASINS
A
B
C
D
E
FINAL CLARIFIER NO. 2
FINAL CLARIFIER NO. 1
DISCHARGE TO RIVER
MUNICIPAL GRIT COLLECTORS AND PARSHALL FLUME
CONTROL BUILDING
INDUSTRIAL WHITEWATER
WET WELL & BAR SCREEN
CHLORINATION CHAMBER
CHLORINATION BUILDING
MUNICIPAL WASTEWATER FORCE MAIN
INDUSTRIAL WASTEWATER INFLUENT SEWER
LEGEND
MUNICIPAL AND INDUSTRIAL WASTEWATER FLOW
SLUDGE FLOW

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD. BEGIN SECTIONS HERE
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

Poor process performance has plagued the treatment facility since its startup in November of 1975. In general, the major problem has been related to the predominance of filamentous bacteria in the activated sludge process. Classic bulking sludge problems have resulted in massive losses of process solids, unstable operation, and repeated violations of discharge standards. Prior to the work described in this paper, a variety of measures taken to eliminate the bulking sludge problem had been unsuccessful, making control of the process extremely difficult and satisfactory operation impossible.

As a result of the continued poor performance of the treatment facility, pressure by the regulatory agencies led the city and industry to employ the author as a consultant. The ensuing evaluation, field work, and solution implementation effort by all parties involved has resulted in significant design modifications to the facility and some interesting findings concerning joint treatment of a fine paper mill wastewater.

PERFORMANCE EVALUATION

This section briefly summarizes the work conducted at the treatment facility during the last 16 months. The objective during the period has been to achieve a stable activated sludge process operation through the elimination of conditions which promote the predominance of filamentous microorganisms in the MLSS. The work has progressed through an iterative process involving: 1) evaluation, 2) solution implementation, and 3) re-evaluation, to achieve the objective. The results can be separated into the four basic phases described below. The complete information describing the study up to and including Phase III is contained in an engineering report written for the city (3).

Phase I

At the beginning of Phase I, the aeration process was dominated by three species of filamentous bacteria and solids could not be maintained due to severe bulking conditions present in the secondary clarifiers. In an attempt to determine the environmental factors responsible for this condition, a preliminary evaluation of past operation and performance was performed. The results of that evaluation are summarized below:

1. Municipal Raw Wastewater - daily grab
    a. Average BOD_5 - 170 mg/L
    b. Average SS - 112 mg/L
    c. pH range - 6.4 to 9.2

2. Paper Mill Raw Wastewater - daily composite
    a. BOD range - less than 200 to over 1300 mg/L
    b. SS range - less than 200 to over 2500 mg/L
    c. pH range - 4.3 to 9.4

3. Primary Effluent - Combined
   a. BOD_5 - 2 grab samples per month routine
      - 21 composite (24 hr) samples represented in Figure 2 indicated reasonable loading based on very limited data
      - data in Figure 3 indicated effective removal by primary system
   b. SS - 16 grab analyses average 67 mg/L
   c. pH - no routine analyses
   d. Alkalinity - 1 grab per week ranged from 44 to 107 mg/L as $CaCO_3$

4. Aeration System
   a. Nitrogen - not measured
   b. Phosphorus - not measured
   c. pH - not measured
   d. Dissolved Oxygen (D.O.) - measured once per day; periods of low D.O. were indicated occasionally but generally in excess of several mg/L.

5. Effluent - measured concentrations of N and P indicated that insufficient levels existed in aeration system.

6. General Process Performance
   a. Brief periods of good operation (SVI 100) had occurred in the past, generally corresponding to periods of excess NH_3-N as evidenced by nitrification.
   b. Previous efforts to solve the operational problems included chlorine addition, lime addition, nitrogen and phosphorus addition, commercial bacteria additives, and polymer addition to the secondary clarifier. In general, these efforts had been unsuccessful for a variety of reasons.

The preliminary evaluation of operations clearly indicated that several fundamental requirements were not being satisfied at all times. The result of this situation had been the predominance of filamentous microorganisms, bulking sludge, and generally unstable operations. Since the data were limited and incomplete, an intensive short-term analysis was conducted to obtain more complete information with respect to key aeration system parameters. The pertinent results of the evaluation are detailed below:

1. Hydrogen Ion Activity - pH

   The pH was monitored hourly for a three-day period on the aeration system, primary effluent, mill wastewater and city wastewater. The data did not indicate any significant problems; however, aeration system pH was between 6.5 and

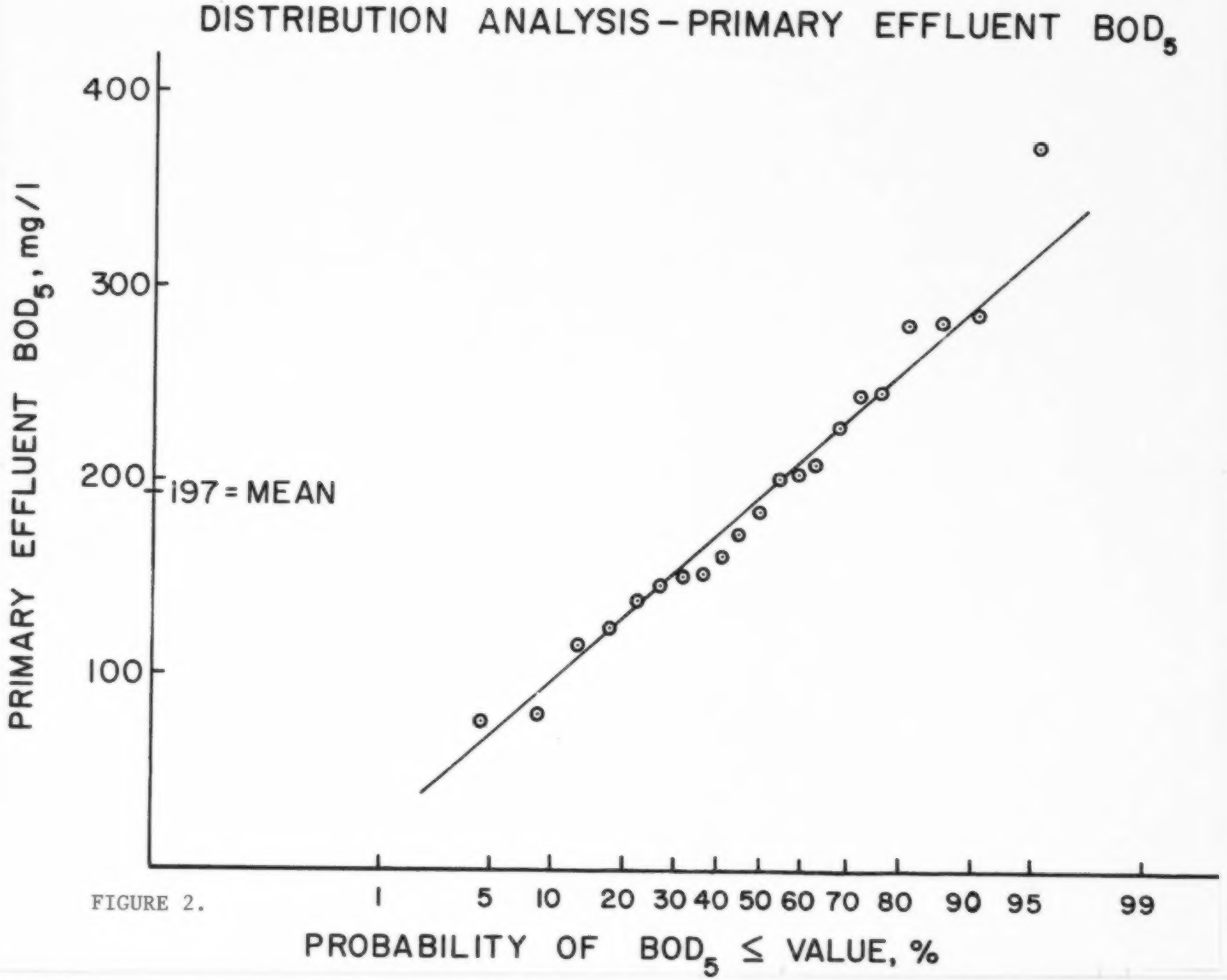

DISTRIBUTION ANALYSIS - PRIMARY EFFLUENT BOD5
PRIMARY EFFLUENT BOD5, mg/l
400
300
200
197 = MEAN
100
1
5
10
20
30
40
50
60
70
80
90
95
99
PROBABILITY OF BOD5 ≤ VALUE, %

FIGURE 2.

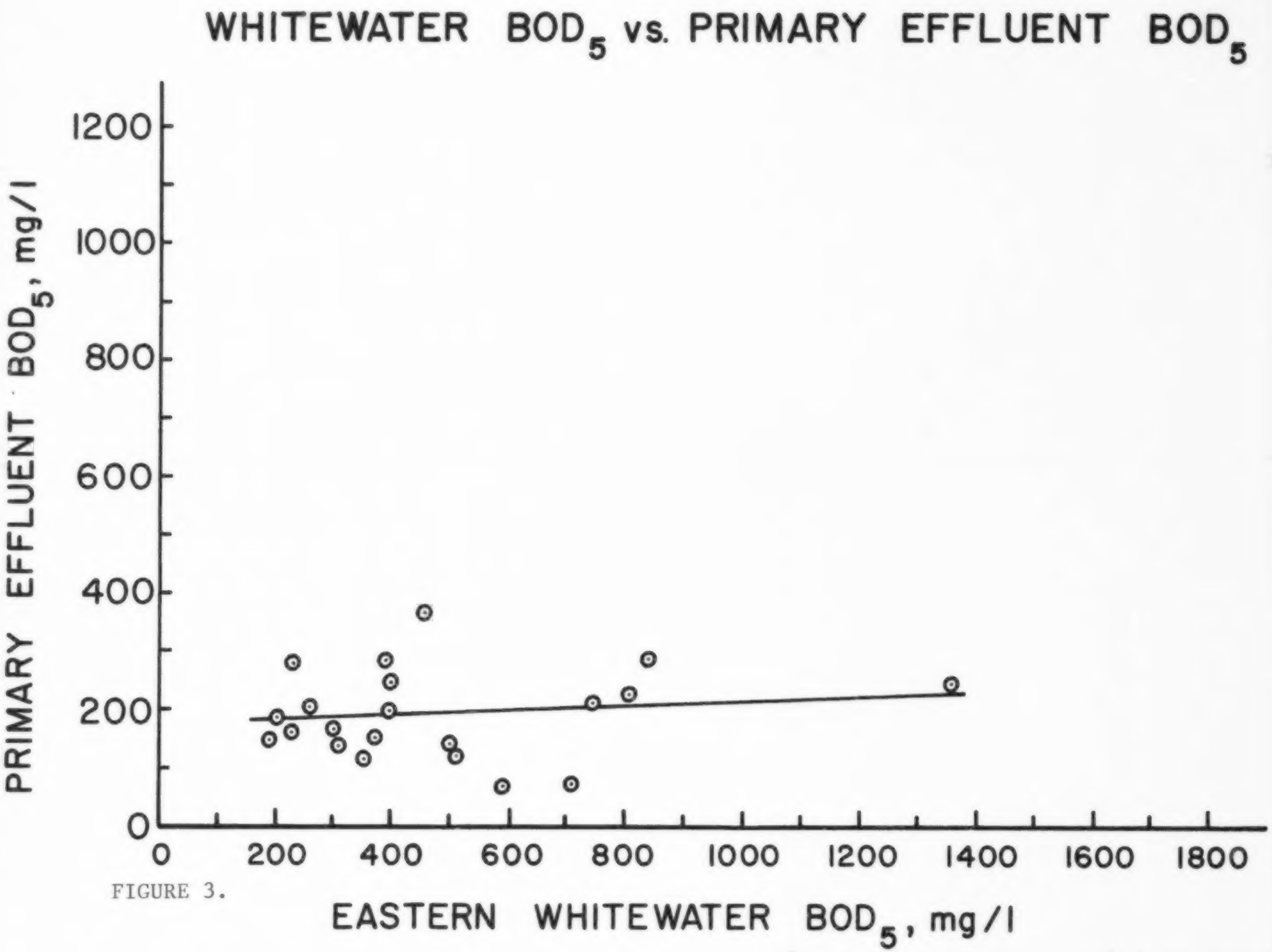

WHITEWATER BOD5 vs. PRIMARY EFFLUENT BOD5
PRIMARY EFFLUENT BOD5, mg/l
0
200
400
600
800
1000
1200
0
200
400
600
800
1000
1200
1400
1600
1800
EASTERN WHITEWATER BOD5, mg/l

FIGURE 3.

7.2 during most of the period. In general, it appeared that increased alkalinity might be required in the future.

2. Nitrogen

Influent and aeration system ammonia and nitrate levels were measured hourly during the three-day period. BOD_5 and organic nitrogen levels were measured for 3-hr composited samples. The ammonia and BOD_5 data are presented in Figure 4 and show the addition of 52 lb/d of supplemental NH_4-N which was being added from drums at the time. As expected, the carbohydrate-dominated wastewater from the mill contributed only a small amount of nitrogen. Based on the traditional ratio of 20/1 for BOD_5/N, it was clear that even with the supplemental nitrogen addition the combined wastewater was marginal in terms of nutrient supply. Data on organic nitrogen indicated that most was lost in the primary system. Nitrate concentrations were generally less than 1.0 mg/L.

Aeration system data indicated that all the influent ammonia was being utilized during a significant portion of the three-day period (10 hr), and this is shown graphically in Figure 5. It is important to note that nitrate levels also indicated utilization during the heavier loading periods. It is important to note that the BOD_5 loading (see Figure 4) measured during the period was below the average design level of 4690 lb/d (195 lb/hr). Therefore, deficient nitrogen levels were present during conditions of below average BOD_5 loading.

3. Phosphorus

Dissolved phosphate analyses were performed on 100 hourly grab samples and the results are summarized in Table 2.

TABLE 2. DISSOLVED PHOSPHORUS RESULTS
(values in mg/L PO_4-P)

Sample	Analyses	Range	Average	Comment
Mill	20	0.0 - 0.3	-	16 values = 0.0
City	32	0.2 - 10.6	1.9	very erratic
Primary Effluent	31	0.0 - 2.2	1.0	very erratic
Aeration Basin 1	8	0.1 - 2.3	1.0	erratic
Aeration Basin 2	9	0.3 - 1.5	1.0	erratic

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD. BEGIN SECTIONS HERE
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS

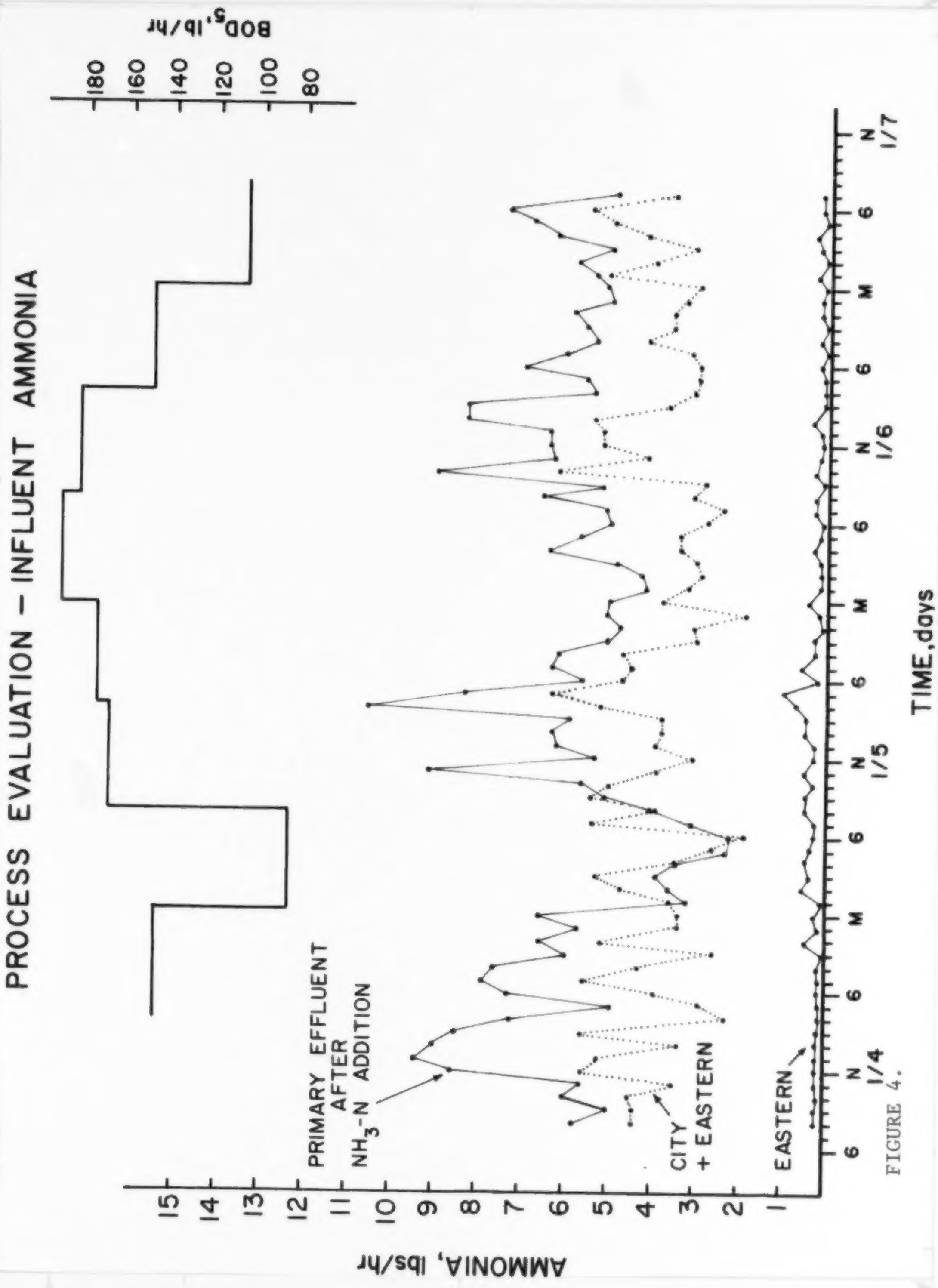
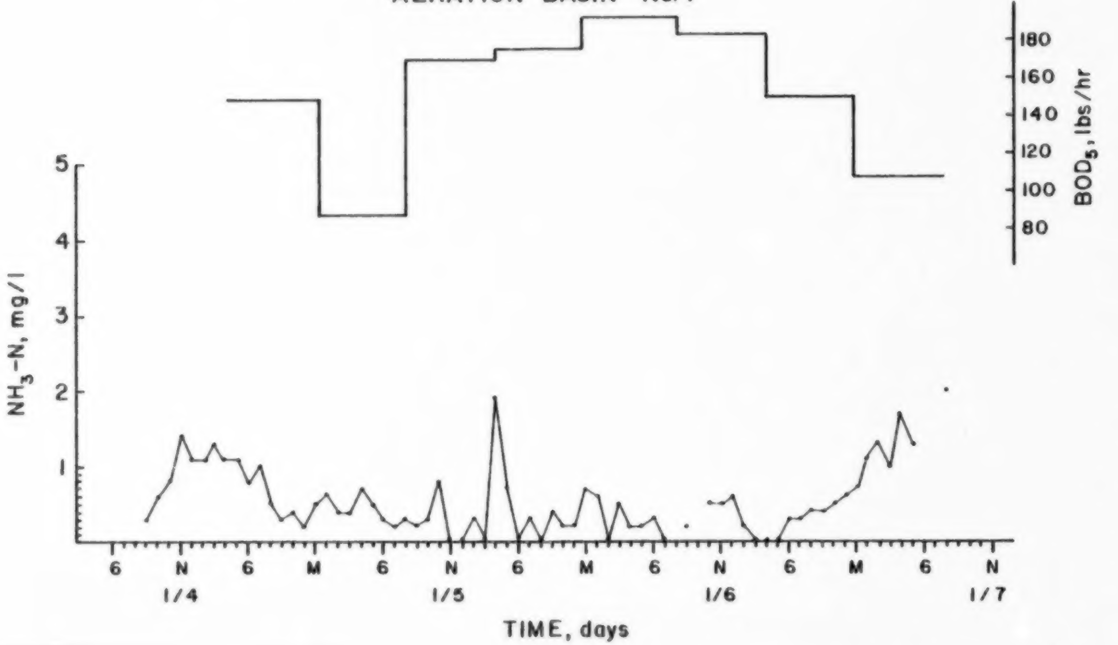


FIGURE 4.

FIGURE 5

PROCESS EVALUATION - AMMONIA IN
AERATION BASIN No. 1



Based on an average BOD_5 of 200 mg/L and the traditional BOD_5/P ratio of 100/1, a deficiency in dissolved phosphorus was indicated. The average concentration entering the aeration process was only 1.0 mg/L, or about 50% of that required. An explanation for the dissolved phosphorus concentrations present in the aeration system might be that BOD metabolism was limited by the deficiency of nitrogen that existed. It should also be noted that the levels measured in the city wastewater were low compared to the average for municipal facilities.

Based on the results of the evaluations conducted during Phase I, it was recommended that bulk nitrogen and phosphorus addition systems be installed as permanent facilities at the treatment plant. An alkalinity system was recommended as a possible future requirement, to be decided upon after the effects of adequate nitrogen and phosphorus addition on process performance had been determined.

Phase II

Phase II was the field implementation of the recommendations for correction of N and P deficiencies. Since the installation of permanent bulk chemical storage facilities would require several months, the field trial proceeded using chemical feed pumps and 55-gallon barrels of aqua ammonia and phosphoric acid. The N addition objective was to maintain a minimum of 5 mg/L of nitrogen as a combination of NH_3-N and NO_3-N in the aeration basin. Later it was found that this residual had to be increased during certain periods due to extremely erratic demands. The dissolved P objective was 2 mg/L in the aeration system. These excess concentrations were maintained to ensure adequate nutrients at all times. D.O. concentrations were also maintained at excess levels for the same reason. Since the addition of excess N, P, and D.O. was expensive and more could be learned by using one aeration system as a control, supplemental N was not added to aeration basin No. 2 during the field study. Using this approach, two identical parallel systems were used to study the nitrogen requirements of the combined wastewater treatment.

The results of Phase II consisted of two separate periods of field study: 1) initial operation during high spring infiltration/inflow and 2) later operation during normal city flow in the summer. Since the process was in an upset condition going into the high flow period, it was difficult to establish a stable operation until the flow subsided some weeks later. However, some useful information was gathered in a three-week period prior to the higher flow.

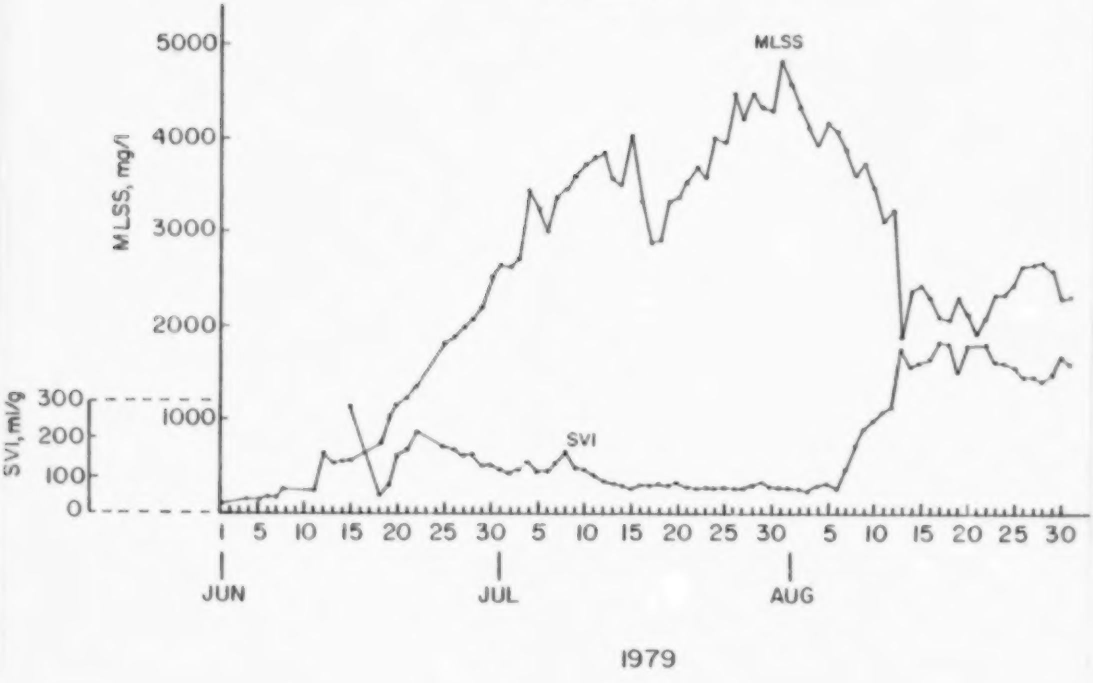
With the initial addition of excess N and P to aeration system No. 1, immediate improvement occurred. The MLSS increased from startup conditions of 200 mg/L to approximately 2000 mg/L in a one-week period, and the facility was meeting discharge standards. An industrial loading event occurred at that point and, in spite of excess N, P, and D.O. concentrations, a filamentous bacterial species became established in less than 12 hr. Subsequent short-term erratic loading from the mill caused further deterioration in process stability and bulking conditions were severe by the end of the third week. Due to additional erratic loading and infiltration/inflow events the field trial was unsuccessful until the spring runoff subsided. What was significant at this point was the near continuous data which was gathered on aeration system loading. It became clear that additional evaluation and monitoring of organic loading would be necessary.

During the second attempt at providing excess N and P concentrations some meaningful data were collected on process performance. In general, an excellent stable operation was achieved in aeration system No. 1 (with supplemental N), and a less stable operation was attained in aeration system No. 2. Effluent standards were met for more than one month and performance was better than any that had occurred at the facility since its startup. Figures 6 and 7 are a summary of process performance in terms of solids and settleability. While the data indicate only slightly improved stability in aeration system No. 1, actual field performance of aeration system No. 2 was much less stable. Several times during the period from late June through early August, system No. 2 was close to upset and had a significant amount of filamentous bacteria present until the final days of July. In contrast, system No. 1 was extremely stable for nearly one month and was much less sensitive to erratic short-term loading from the mill.

The reason for the observed and measured performance differences between the two aeration systems can be seen in the nitrogen data illustrated in Figures 8 and 9. In Figure 9 it is clear that without supplemental N, the naturally occurring N level was marginally adequate most of July, with nitrification being complete when excess NH_3-N was available. The one period in July of complete deficiency (7/20) is also reflected in the SVI data of Figure 7, and microscopic analysis indicated a slight increase in filamentous bacteria that subsequently diminished during the next few days with a return to an excess N environment. In contrast, the data of Figure 8 show the relatively high levels of excess NH_3-N and complete nitrification during July and through early August. An important point to note in both figures is the extremely variable demands for N, which also were reflected in the oxygen demand. The increase in organic loading and corresponding large decrease in aeration system N caused rapid filamentous growth at the beginning of the second week in August. Without nitrogen, aeration system No. 2 lost treatment efficiency over a one-week period. With excess nitrogen the filamentous growth in system No. 1 was more extensive and the differences between the two parallel systems can be seen in the SVI and solids data of Figures 6 and 7. By mid-August, treatment in system No. 2 was virtually non-existent and system No. 1 was not meeting standards due to intermittent bulking conditions in the secondary clarifiers.

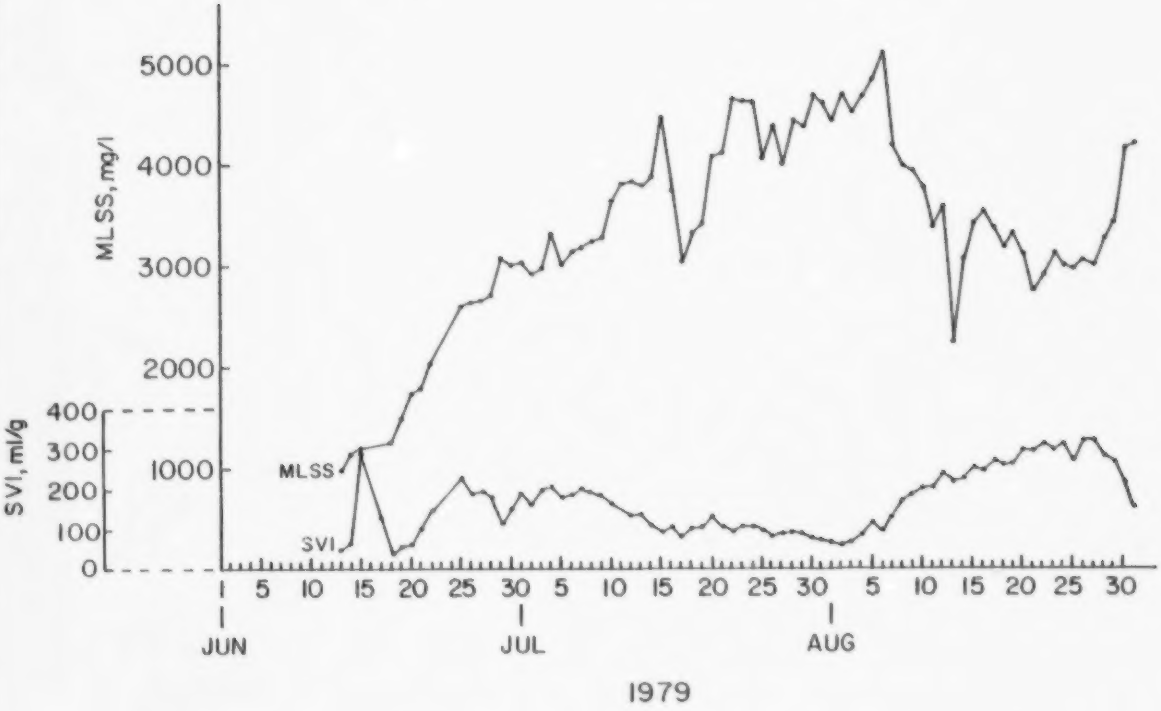
The most important fact derived from the operation depicted by Figures 6 through 9 was that the smaller of the three species of filamentous bacteria established in the MLSS under conditions of excess N, P, and D.O. Thus, it became obvious that a re-evaluation of the operating conditions was required to arrive at a solution which could be implemented to achieve the original objective. Actually, this third phase of evaluation had already been started

MLSS & SVI SYSTEM 1, JUNE-AUGUST
FIGURE 6



MLSS & SVI SYSTEM 2, JUNE-AUGUST

FIGURE 7



at the end of June after preliminary data in the spring had indicated problems with the erratic loading from the paper mill.

Phase III

In an attempt to monitor the loading to the aeration system and establish the conditions which caused process problems to occur, the chemical oxygen demand (COD) and suspended solids (SS) were monitored during late June through July, and for a five-day period in mid-August. These data are shown in Figures 10 and 11. Since it appeared that the problems of the treatment facility had been solved by late July, the monitoring was discontinued only a few days prior to the establishment of filamentous bacteria.

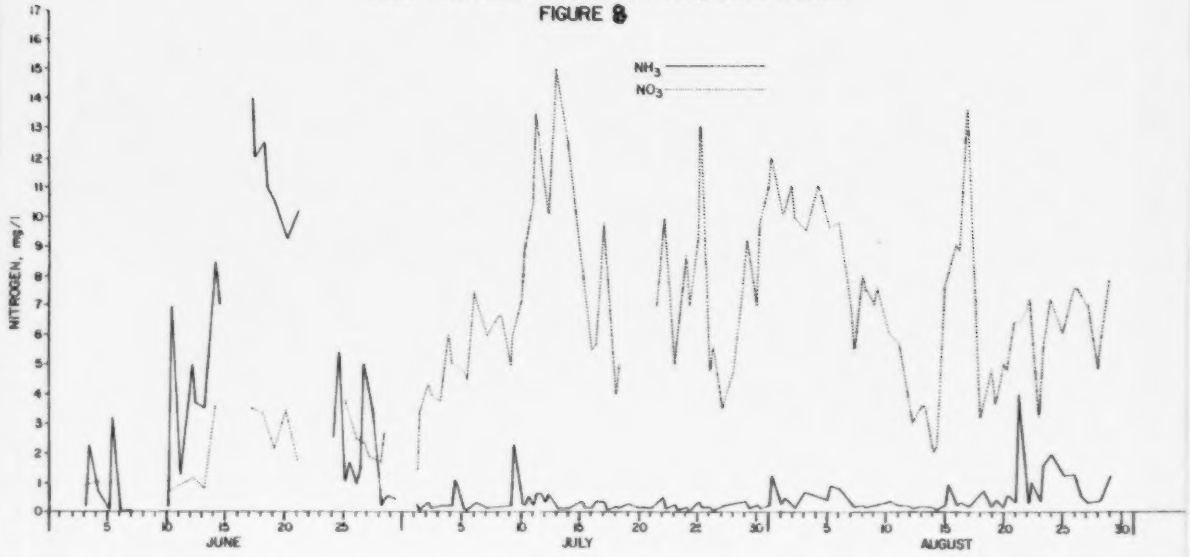
The COD data of Figure 10 do not indicate any clear explanation to the return of process problems in early August, since the actual samples for the onset of problems were not available. However, loading was generally higher in late July and in mid-August. It should be pointed out that the process was designed for a BOD_5 loading of 4690 lb/d and that the approximate ratio of BOD_5/COD was 0.55; therefore, the process was not "overloaded" in terms of the intended design criteria. As evidenced by the earlier N data, the loading was actually slightly below normal during most of July.

The SS solids data shown in Figure 11 indicate much higher loading during the period before and after process problems occurred; however, the process was designed for an average SS loading of 3800 lb/d. As with COD loading, it appears that SS was below the design average during most of the period. In comparing the COD and SS data it is clear that there were days of extremely high soluble COD loading; e.g. on 7/20, and this was suspected to be caused by an increased starch content in the mill wastewater.

The data in Figures 10 and 11 were derived from 4-hr. average samples; therefore, an approximation of the diurnal loading was available for analysis. Since the true cause of the process problems was not clear from the daily averages, a more detailed loading evaluation was necessary. This evaluation consisted of comparing the diurnal loading patterns for days of excellent, stable process operation and days prior to and after the process problems returned. These comparisons are summarized in Figures 12 through 14. The loading on July 4 shown in Figures 12 and 13 represent the approximate city loading after primary treatment, since the mill was shut down for the holiday.

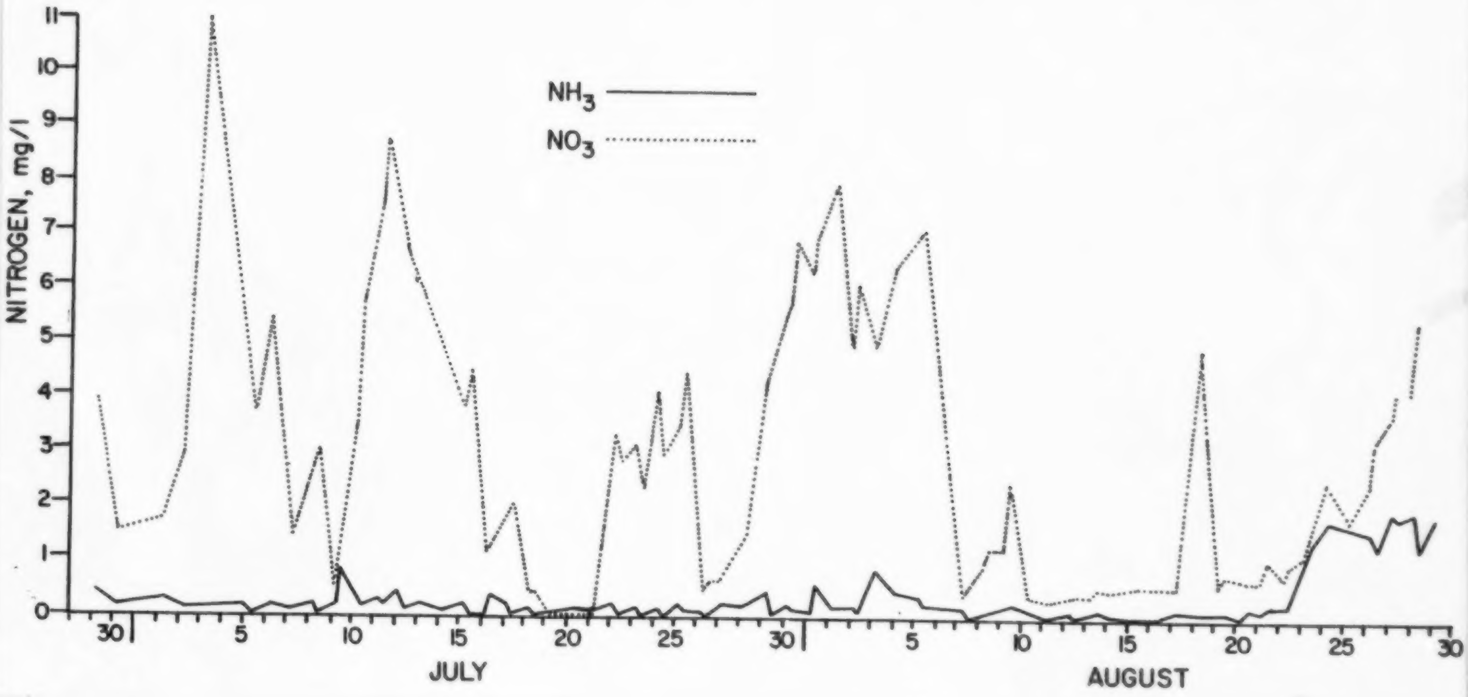
The differences in loading patterns for the days shown are apparent. Also, the influence of the mill wastewater is clear by noting the low loading on July 4. The period that appeared to initiate the process problems in early August is indicated by the flow data for the mill shown in Figure 14. As a comparison, a day from the period of excellent process operation is also shown. The differences between the two flow records are due to the dumping of process tanks at the mill, which is normal in the operation of the papermaking process when machines are periodically shut down for a variety of reasons. It is also important to note that these "dumps" were not violations of the influent agreement the mill has with the city, or what was anticipated by the design engineer. Average influent loading limits had been exceeded on certain days during the period and this undoubtedly compounded the problem; however, a thorough data analysis indicated that the short-term loading

SIDE I-NITROGEN CONCENTRATIONS, JUNE-AUGUST
FIGURE 8

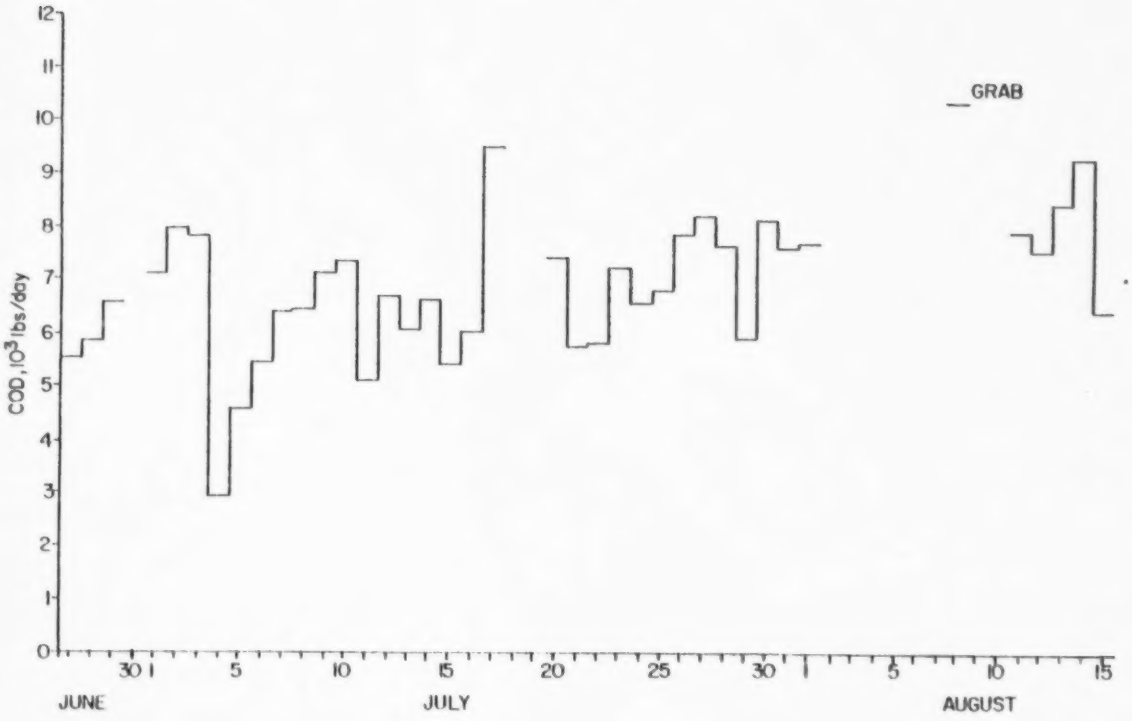


SIDE 2-NITROGEN CONCENTRATIONS, JUNE-AUGUST

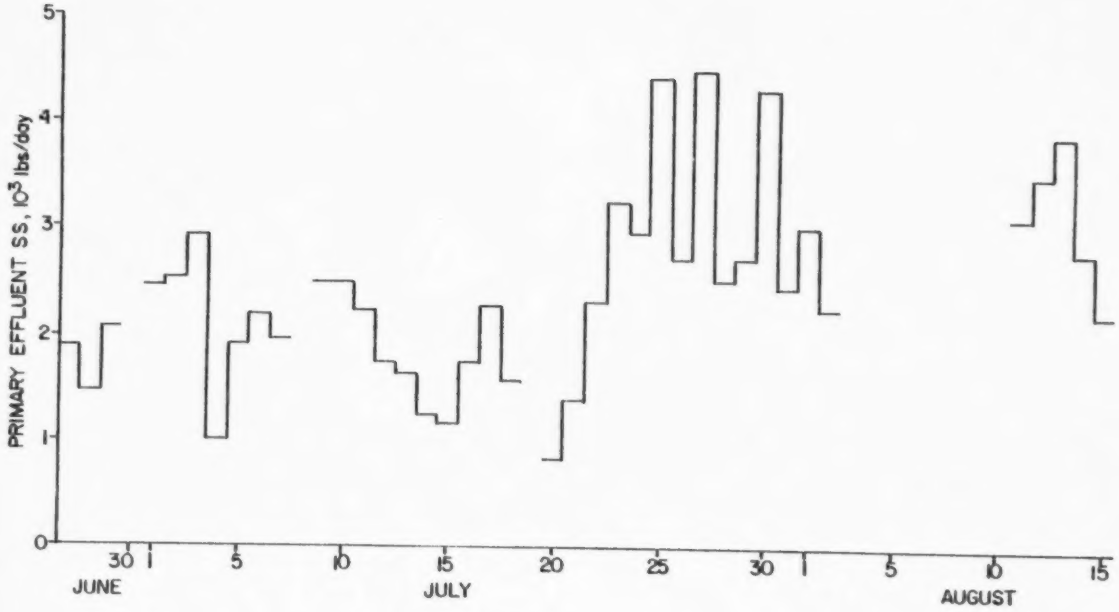
FIGURE 9



PRIMARY EFFLUENT COD-DAILY AVERAGE
FIGURE 10



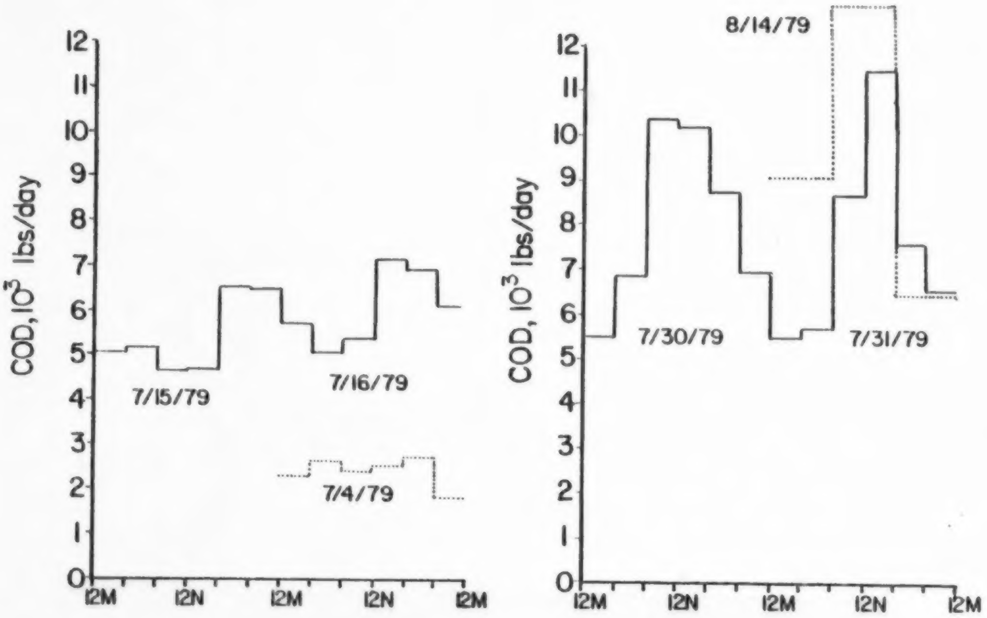
PRIMARY EFFLUENT SS - DAILY AVERAGE
FIGURE II



TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE

PRIMARY EFFLUENT COD - DIURNAL VARIATION

FIGURE 12

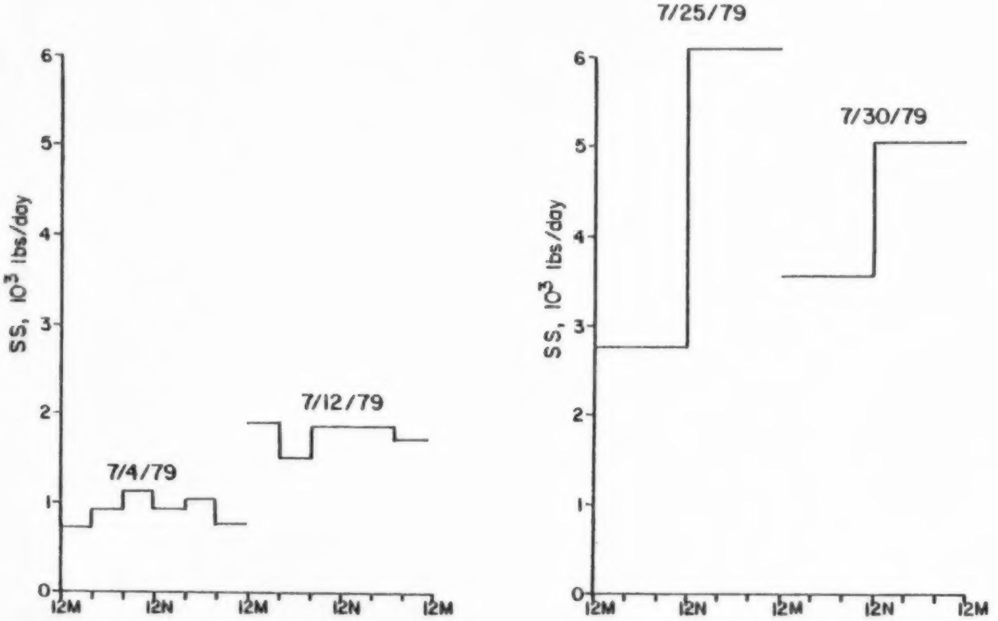


BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS

EPA-287 (Cin.)
(4-74)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

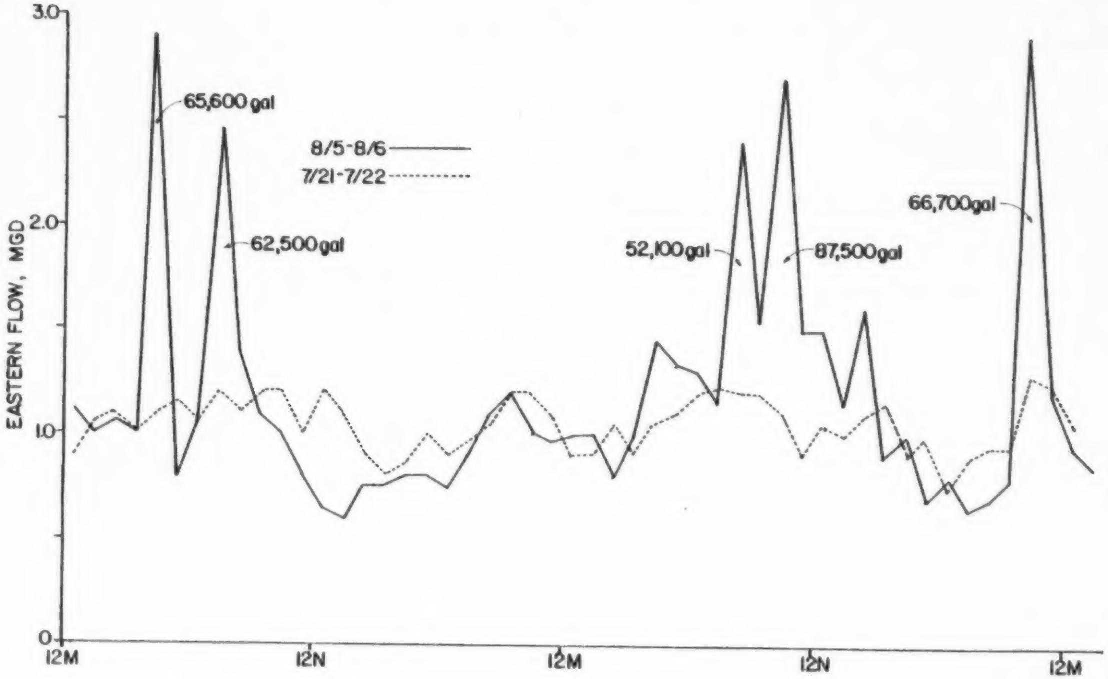
PRIMARY EFFLUENT SS-DIURNAL VARIATION
FIGURE 13



BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS

EPA-287 (Cin.)
(4-76)

EASTERN FLOW-DIURNAL VARIATION
FIGURE 14



variation was the real problem and this type of event could occur when the average daily loading from the mill was near normal. In addition, on most days of exceedingly high mill loading the primary system acted as an effective buffer to the aeration system. The problem was found to be related to loading events in which the ratio of mill/city BOD_5 was at a maximum, and this could be caused by infrequent poor SS removal in the primary or a discharge of soluble COD.

Aside from the problems with the growth of filamentous bacteria, the erratic loading events caused obvious process problems related to nutrient addition and D.O. control. Both were controlled manually, based on monitoring data, and were subject to any variation which occurred in process loading. To ensure adequate levels of N, P, and D.O., the uneconomical approach of maintaining significant excesses was necessary. These considerations, along with others relating to process stability, led to the conclusion that any future solution approach would have to be directed at changing the wastewater loading prior to the aeration system.

The primary question with regard to the predominance of filamentous bacteria was why were they competitive during these particular loading events? Extremely high city loading caused by the initial period of sewer flushing during infiltration events did not stimulate their growth. In fact, these periods usually were followed by an improved bacterial population. Based on all the available data concerning the operational characteristics of the activated sludge process, it was concluded that the susceptibility of the process to the establishment of filamentous sludge was probably due to the unbalanced nature of the wastewater. The mill wastewater is primarily carbohydrate in nature, containing paper fiber, sizing starches, etc., which are naturally low in nutritional value. It is believed that during periods of high mill/city BOD loading these carbohydrates present a problem from the standpoint of being nutritionally poor, and this condition results in a filamentous -activated sludge. Data indicated that the ratio of mill/city BOD was normally about 3.5/1, but increased to greater than 10/1 during the short-term loading events.

Several basic solution approaches were considered, but only those which would reduce the ratio of mill/city BOD loading to the aeration system and attenuate the loading variations were regarded as reasonable permanent solutions. They would result in a more nutritionally balanced wastewater by increasing the impact of the well-balanced city wastewater relative to the carbohydrate wastewater of the mill. Three steps were considered:

1) A reduction of mill loading,

2) An increase in city loading,

3) Both 1 and 2.

With respect to the magnitude of total load, methods 1 and 2 would have been opposite in effect; i.e., 1 would have reduced the magnitude and 2 would have caused an increase that would have overloaded the aeration system. The net effect of method 3 depended on the magnitude of change in 1 and 2 that could be achieved.

Based on the considerations summarized above, recommendations were made to provide a solution to the remaining problems. An effective spill control system was recommended as the most desirable solution; however, for economic reasons it was decided that the feasibility of polymer addition to the mill wastewater should be investigated. With polymer addition data from preliminary experiments conducted previously by the industry, it appeared that this would be a viable alternative, in conjunction with a by-pass of municipal wastewater directly to the aeration process. A design modification to the plant piping system was required to accomplish the by-pass due to a problem with the original by-pass design.

Phase IV

Additional laboratory work at the mill allowed the selection of a polymer for a field trial, and a re-piping design modification for the municipal by-pass was made. The field trial began in mid-February and the results to date are encouraging. Since the results are tentative, definite conclusions cannot be made; however, it is important to note the changes that have taken place since the implementation of the field trial:

1) Bulking sludge problems have been eliminated in both aeration systems. Note: The bulk N and P addition systems were operational prior to the implementation of the changes, and both aeration systems receive nutrients.

2) Discharge standards are presently being met.

3) Overall average loading to the aeration process appears to be higher with the change in wastewater character. Limited data indicate that a very high fraction of municipal BOD had been removed with the mill wastewater in primary treatment.

4) The activated sludge has taken on a much healthier dark color as a result of the increased inert solids contained in the city wastewater. Prior to the by-pass, the MLSS always took on the color of the variable mill wastewater.

5) The SVI has become established at a level of 70-90, and the process appears to be reasonably stable.

6) Polymer addition has had a beneficial effect on solids dewatering, producing a large decrease in sludge volume.

In addition to the solution implementation activity of Phase IV, other important work is being directed at characterizing the mill wastewater and aeration system influent. A detailed sampling and analysis program is being conducted to better define the loading parameters. Two months of data collection for total COD, soluble COD, SS, and starch has yielded some very useful information on the critical mill operations as they relate to the resulting wastewater. Also, this effort will allow the effectiveness of polymer addition to be completely evaluated over an extended period.

DISCUSSION

In the course of solving a number of activated sludge process problems similar to the one described in this paper, the author has observed that certain key fundamental oversights in design and operation tend to be made all too often. Sufficient emphasis is not put on ensuring that a proper aeration system environment will be maintained at all times. This critical area of process design is especially important in situations where troublesome industrial wastewaters are encountered, as evidenced by the example discussed in this paper. The following discussion includes specific comments about the Brewer joint treatment facility, as well as some general comments related to design and operation of similar facilities.

Adequacy of Original Design

The original design of the Brewer treatment facility did not give proper consideration to the variability in magnitude and character of the industrial wastewater. Average values for loading were not sufficient to ensure the maintenance of a proper aeration system environment. The diurnal loading examples shown in Figures 12 through 14 were found to be critical factors in the establishment of bulking problems. In general, extremely high loading periods that cause deficient environmental conditions to exist, even for only short periods, can be detrimental to process stability. In the case of Brewer, the relative short-term periods of high loading accounted for much of the entire organic load during the day. This loading, in turn, produced much of the net microbial growth for the day. Since these periods of high loading stimulated the growth of filamentous bacteria, establishment of bulking conditions was very rapid. The variability in character of the mill wastewater was also neglected. It has been found that there are periods of mill operation in which solids (fiber) do not settle. Prior to polymer addition these events overloaded the aeration process. Also, the character of the mill wastewater is highly variable in terms of the soluble starch content, and this is also an important factor to aeration system loading.

Design consideration for N and P addition was made in relation to average conditions. Therefore, the failure to recognize the deficiencies which could occur with higher than average mill loading caused the designer to incorrectly assume that the city wastewater could supply excess N and P. The importance of N and P is well documented and should always be given proper consideration with a nutritionally poor wastewater.

Beyond N and P, the lack of either a trace mineral or key amino acid (protein) or vitamin could have been considered. The literature clearly reflects problems of this nature associated with wastewaters having a nutritionally unbalanced character. Sawyer (4), in 1940, discussed the problems a small city would have when it accepted the wastewater of an industry of this type. Further, the natural surface water supply for the Brewer area is extremely devoid of dissolved minerals. Several key mineral elements are routinely reported as being absent in the water analysis for the city. This water is among the softest in the country, at levels of hardness around 10 mg/L as $CaCO_3$. While it has not been determined that a mineral deficiency was the true cause of the problem during high carbohydrate loading, the nature of the water before contamination certainly is very low in mineral content. It could be speculated that with very high carbohydrate loading, the mineral pickup through domestic use might not be adequate to supply the required key trace minerals important in the metabolism of these compounds. At a minimum, the design could have taken the direction of the work described in this paper; i.e., minimize the unbalanced character of the combined wastewater.

As a summary, the following design modifications have been required to date:

1) Installation of a 10,000 gal. bulk anhydrous ammonia nitrogen addition system.

2) Installation of a 4,000 gal. bulk phosphoric acid addition system.

3) Modification of plant piping system to allow proper by-pass of the city wastewater to the aeration system.

4) Installation of a permanent polymer addition system at the mill.

Operation and Process Stability

The sophistication of the intended operation was not adequate. Since the variability of the mill wastewater was not given proper consideration, many additional operation requirements are necessary. The plant was designed without provision for any automated D.O. monitoring system, and for single-shift operation during the day. Therefore, no means of controlling the aeration rate in response to the highly variable loading was provided during most of each day. Addition of N and P for economic operation now requires a minimum monitoring test once every three hours, on a 24-hr. basis. Even with this degree of monitoring, both N and D.O. can reach critical levels between sampling times. Unfortunately, there is no predictable pattern of variation as one finds with municipal wastewater. High demands can occur at any time, and the operator must be able to respond. This requires an increased operations effort compared to what was originally anticipated.

In general terms, an activated sludge process must have sufficient "dynamic stability" to handle extremes in loading. Very few treatment facilities are without loading variation. Domestic or municipal plants are subject to diurnal hydraulic and organic loading variations which are reasonably consistent and predictable. While these variations cause related variation in process performance parameters, the extremes are such that attenuation of influent loading is rarely required. Since diurnal patterns are consistent over time, the process will respond naturally to the influent loading.

Industrial wastewaters are entirely different than domestic or municipal wastewaters, in terms of influent loading variation. Rather than reflecting the habits of a community population, the wastewater variations result from industrial processes and related operations. Where extremes in loading are significantly greater than a comparable municipal wastewater, the designer must provide some method of attenuating these extremes or suffer a loss in process stability. Examples of design decisions that might accomplish this are spill prevention basins, equalization basins, aerated lagoon treatment, or the option of joint treatment.

For Brewer and Eastern Fine Paper Company, the option of joint treatment was intended to provide the Eastern wastewater with nutrients, necessary for biological treatment. In this specific situation, the original joint facility process design was risky, at best. The industrial loading required that supplemental N and P be added, and created aeration system loading extremes that put severe stress on the biological process. This resulted in a complete loss of dynamic stability through the establishment of a filamentous sludge. Being a relatively high-rate process the facility could not handle the combined wastewater without additional industrial loading attenuation prior to the aeration system.

Future Work

Future work at the mill and treatment facility will be conducted to ensure that the discharge standards are met at all times and at a minimum operation cost. Past operation has been expensive in terms of the required design modifications, excess power costs for maintenance of high D.O. levels, N and P addition without bulk chemical economics, continuous polymer addition,etc. It is anticipated that future costs will be minimized as the new process operation is optimized.

Continued work at the mill will include additional effort with the polymer system and a completion of the wastewater characterization program. Some possible residual problems with the chemistry of the mill wastewater may require further study to define the impact of clay, suspended fiber, and starch on the process. The mill has exhibited an excellent attitude concerning the implementation of the recommended solution and has been a key participant in the progress made to date.

Work at the treatment plant will be continued to:

1) optimize the N and P addition levels,

2) define the new aeration system loading more thoroughly,

3) determine the operational staffing which will be required for monitoring purposes on a continuous basis,

4) provide an adequate D.O. monitoring system.

Regulatory Aspects

The Brewer, ME. situation raises some interesting questions with regard to responsibility for correction of problems that are associated with the original design of a treatment facility. In this case it was up to the city and industry to provide a solution to a problem that was largely due to the initial design and subsequent approval by the regulatory agency. All costs for solution were provided by the city and industry. These costs could have been funded along with the facility had the designer provided a proper design initially. While it is probably true that no design is perfect, a better design should have been provided in this case. This becomes especially important when one considers the resulting expense and effort the city and industry expended to accomplish the progress made to date.

In arriving at a solution to a problem of this nature, several key ingredients are required:

1) a fundamentally sound solution approach,

2) ample leniency by the regulatory agencies to allow time for proper evaluation of the problem and solution implementation,

3) adequate cooperation between the municipality and industry.

All three requirements are critical to the success of the effort, and the loss of one or more elements creates a severe setback in the rate of progress. While there are always some disagreements between the parties involved in such matters, in this case it was fortunate that cooperation between all parties concerned ultimately has resulted in what is hoped to be a permanent solution.

REFERENCES

1. Gray A. C., et al., "Operational Factors Affecting Biological Treatment Plant Performance," presented at the 51st Annual Conference of Water Pollution Control Federation, Anaheim, CA, 1978.

2. Hegg, B. A., et. al., "Evaluation of Operation and Maintenance Factors Limiting Municipal Wastewater Plant Performance - Phase II," presented at the 51st Annual Conference of Water Pollution Control Federation, Anaheim, CA, 1978.

3. Lowry, J. D., Wastewater Treatment Performance Evaluation - Brewer, ME, Vol. 2, November, 1979.

4. Sawyer, C. N., "Activated Sludge Oxidations - The Influence of Nutrition in Determining Activated Sludge Characteristics," Sewage Works, 12, 1, January, 1940.

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

PB83-142380

UNIROYAL CHEMICAL'S EXPERIENCE WITH COMBINED MUNICIPAL-INDUSTRIAL WASTEWATER TREATMENT AT ELMIRA, ONTARIO

K. C. Bradley
Uniroyal Chemical,
P. O. Box 250, Elmira, Ontario, N3B 3A3, Canada.

ABSTRACT

The Chemical Division of Uniroyal Ltd. produces in Elmira a wide range of organics for use in the agricultural and rubber chemical industries. Process waste waters from this chemical complex are combined with raw sewage from the Town of Elmira prior to primary clarification and secondary treatment in a joint municipal/industrial treatment system. Some of the implications of the way we chose to accept the concept of combined treatment are presented. Because we have experienced treatment in this Ontario Ministry of the Environment operated shared cost plant for the past fourteen years, some thoughts on operating experience are also presented. Changes made, and proposed, to up-grade treatment include modifications to the aeration system, improved equalization, activated carbon pretreatment, and effluent filtration. Studies providing direction for these changes have been carried out by the Ministry of the Environment and by Uniroyal.

INTRODUCTION

The Chemical Division of Uniroyal Ltd. produces in Elmira wide range of organics for use in the agricultural and rubber chemical industries. During the mid-nineteen fifties the Town of Elmira and Uniroyal recognized that additional treatment was necessary for the aqueous wastes from both sources.

TEXT

The close proximity of the Town of Elmira and Uniroyal sewer discharges (see Figure 1), the possibility of similar treatment processes, and the economics of a shared plant as opposed to two separate systems, provided all that was necessary for the study of a co-operative effort for waste water treatment. In fact, laboratory and pilot studies by Uniroyal Chemical soon indicated that we might treat our entire process waste waters in a shared activated sludge treatment plant for less than the chemical costs used to treat one major process waste stream.

Several concepts were examined by Uniroyal including the following:

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER

EPA-287 (Cin.)
(4-76)

1. Separate treatment;
2. Combined treatment;
3. Combined treatment with separation of clean cooling water; and
4. Separate treatment with separation of clean cooling water.

The most reasonable and cost-effective approach seemed to be the third concept and for three reasons. (1) Much of our clean cooling water was already in separate pipes. (2) A lower volume would reduce treatment plant costs. (3) There was some doubt at that time that activated sludge would really work on the concentrated industrial process wastes alone. Although our industrial process wastes without cooling water were very strong, use of the town sewage as dilution water would ensure that activated sludge could still be a good potential candidate for treatment of both Uniroyal and town waste waters together.

By choosing this joint treatment plant concept with separation of clean cooling water, we were not only choosing the most cost-effective solution for our situation at that time, but we were indirectly committing ourselves to the interesting long term waste treatment policy of maintaining a minimum process waste volume. We were also agreeing to other conditions, namely:

1. We would not have full control over operation of the treatment process.

2. As a major contributor of BOD_5 we could be singled out for any treatment failures or inadequacies of the whole treatment plant. (On the other hand, the combined wastes would tend to moderate effects of an interfering substance from any one source).

3. We would discharge less organics than with two separate plants. Effluent quality objectives at that time included 15 ppm. BOD_5 for each secondary activated sludge treatment plant. Separate plants including a mixture of process wastes and cooling water in one, and town sewage in the other, would have provided for a greater number of lb./day BOD_5 in the total of the two discharges than that from one joint plant receiving only Uniroyal's process waste waters diluted with town sewage.

It is interesting to speculate on how different things might have been had we chosen to build separate plants:

1. It would have cost more for both us and our town.

2. We would have had to operate our industrial waste plant entirely by ourselves.

3. We would have had to locate and use our own industrial treatment plant sludge disposal sites. (In Ontario this would not be easy.)

4. We would not be engaged in cost-sharing discussions every time major changes were considered.

5. Our cooling water most likely would have been used as a diluent; so any additional treatment such as carbon adsorption or effluent filtration would probably reflect the costs of dealing with much larger volumes.

6. A higher degree of treatment would be necessary to achieve the same overall town plus Uniroyal discharge of BOD to the receiving stream. Where pollutants are measured in lb./day as well as ppm., this can be very significant.

Construction of the joint Town of Elmira - Uniroyal Water Pollution Control Plant (WPCP) began shortly after design approval by the old Ontario Water Resources Commission. It was started up in late 1964 as a four-stage plug flow 10.6 hr. aeration detention time system, Figure 2. Probably because of shocks from a variation in waste water characteristics, the system was soon modified to approximate a complete mix system.

This, plus improved equalization at Uniroyal, allowed the bacterial population to stabilize, but effluent quality was still not good. The mixed liquor level was raised to the 5,000 to 8,000 mg./l. level in an effort to get a low soluble BOD_5 in the effluent. Unfortunately for the most part, as the MLSS concentration rose, the specific uptake rate (SUR) dropped so that the overall oxygen utilization barely changed. We then went through our whole manufacturing complex and re-directed all individual waste streams having more than 100,000 mg. COD per litre to alternate disposal outside of Elmira. We reasoned that if we starved the organisms, they would learn to do a more complete job of degrading our complex organics. A low soluble BOD_5 resulted, but the colour and COD still remained high.

At this point we examined the addition of powdered activated carbon to the aeration system, the use of granular activated carbon on the final effluent, and pretreatment of our industrial discharge to the joint WPCP with granular activated carbon. We decided on the pretreatment scheme for two reasons. It was the lowest cost approach and it promised to enable the WPCP to provide a good effluent. Following installation of this system some evidence of nitrification appeared in the WPCP for the first time. Now, several years later, the WPCP must be modified so that the effluent will be nitrified. Had we installed our carbon system on the WPCP effluent, it would have been doubtful that we would ever have a nitrifying bacterial population in the WPCP. On the other hand, with tertiary carbon treatment, maybe nitrification would not be necessary.

Although we use town sewage for dilution, we wonder if some bio-oxidation problems may be caused by the natural changes in the degree of dilution. For example, the town sewage diurnal flow pattern shows variations by a factor of 10 or 20. The same variation, though not as often, can occur from day to day with changes in the weather. We hope the diurnal flow equalization basin proposed for the town sewage will provide the solution to our remaining bio-oxidation problems.

Our combined wastes WPCP is now undergoing a major expansion and up-grading. This is required because of the expansion of the town and general up-grading of effluent criteria. See Figure 3. Because Uniroyal has an

EPA-287 (Cin.)
(4-76)

agreement with the Town for a specified portion of the treatment plant, and contributes to its cost of operation, Uniroyal is a member of a technical committee, along with the Town's consultant, and the Ontario Ministry of the Environment, to determine the most appropriate design to satisfy all our treatment needs. So far the committee has agreed on the design and cost-sharing with Uniroyal for the first part of the expansion / up-grading system. Modifications will, among other things, include the following items:

1. Diurnal flow equalization for the town sewage.
2. Full conversion to the complete mix process.
3. Improved effluent clarification.
4. Final effluent filtration.
5. Discharge of Uniroyal waste directly to the aeration section.
6. Volumetric design capacity increase of 47% to accommodate an increase in the town's population.

The second part of the WPCP up-grading involves nitrification. Laboratory studies for this part are still in progress. Once completed, we will again establish a fair cost share, and then work out a new agreement for sharing the plant operating costs. Because the second phase requires nitrification, it is perhaps fortunate that we long ago separated clean cooling waters from our process wastes. A carbon pretreatment system for five or ten times the volume to remove the organics inhibitory to nitrifying organisms would have been considerably more expensive than the system we installed. If we had the equally more expensive tertiary carbon treatment and still required nitrification in the secondary system, a second carbon system up-stream would represent a comparatively enormous additional investment in treatment costs. This suggests that by minimizing our volume of contaminated aqueous wastes we saved ourselves a great deal in treatment costs initially, now, and in the foreseeable future.

In summary, our joint system indicates the following:

1. Lower total volume (use of sewage as inorganic salt diluent in place of clean industrial cooling water).

2. Less duplication of equipment, manpower, and testing services.

3. Fewer alterations whenever more stringent effluent quality requirements are imposed. (One plant to alter in place of two.)

4. Lower cost pretreatment systems for the industrial wastes. (With cooling water separation a more concentrated industrial waste results, providing a wider variety of applicable pretreatment techniques to choose from.)

This means that for municipal and industrial wastes, I believe that to install and then up-grade a combined treatment system to meet the ever-changing receiving stream requirements should most certainly be lower in cost for both parties than for each to go it alone with separate systems.

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

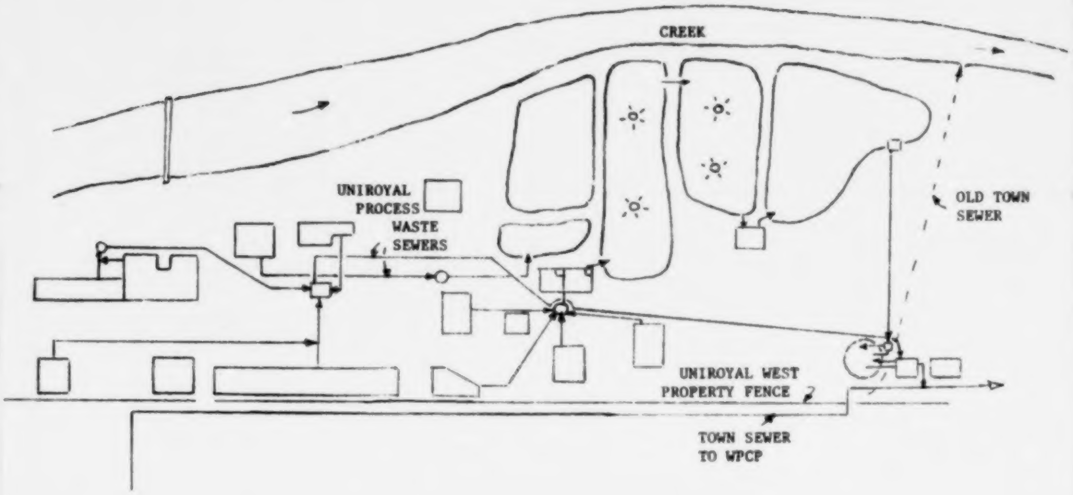

CREEK
UNIROYAL PROCESS WASTE SEWERS
OLD TOWN SEWER
UNIROYAL WEST PROPERTY FENCE
TOWN SEWER TO WPCP

Figure 1. Town of Elmira.

BEGIN LAST LINE OF TEXT
3/8"
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

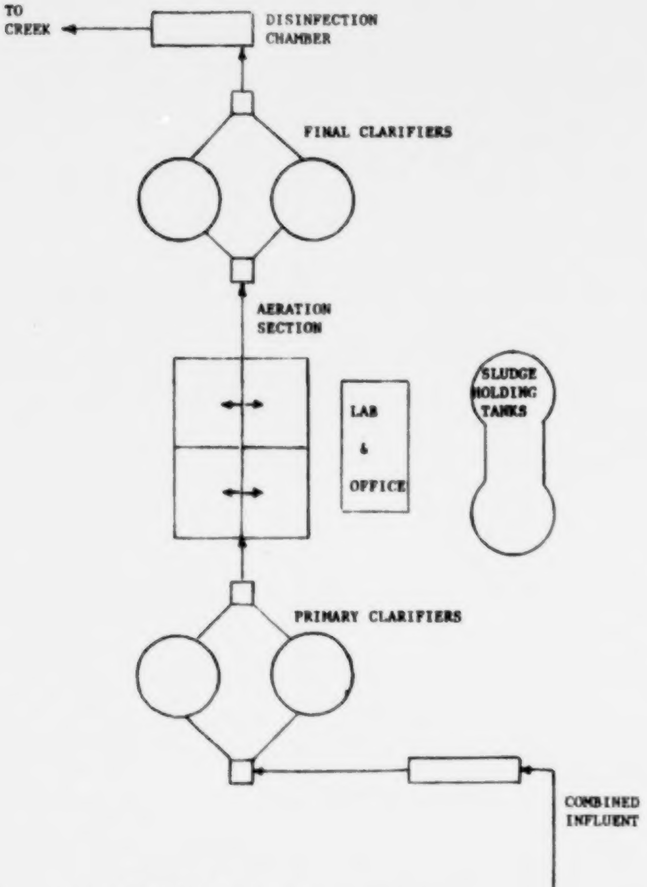

TO CREEK
DISINFECTION CHAMBER
FINAL CLARIFIERS
AERATION SECTION
LAB & OFFICE
SLUDGE HOLDING TANKS
PRIMARY CLARIFIERS
COMBINED INFLUENT

Figure 2. Municipal/Industrial Treatment System.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

FIGURE 3 SOME DISCHARGE CRITERIA CHANGES

Maximum Values For:	1957 Objectives	1972 Requirements	1979 Requirements
BOD_5 (mg./l.)	15	10	7.5 (75 lb./day)
SS (mg./l.)	15	15	15 (150 lb./day)
Phenolic equivalent (µg./l.)	20	20	6.5 (0.065 lb./day)
TKN as Nitrogen (mg./l.)	-	-	3.5 (Apr. 1 to Oct. 31)
Free NH_3 as Nitrogen (mg./l.)	-	-	7.5 (Nov. 1 to Mar. 31)

EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

PB83-142398

INDUSTRIAL COMPATIBILITY WITH THE POTW IN TAMPA, FLORIDA THROUGH CITY/INDUSTRY COOPERATION

D. W. Pickard
City of Tampa
2700 Maritime Blvd.
Tampa, Florida 33605

ABSTRACT

A comprehensive industrial waste monitoring section was started on a full scale basis in 1973, five years before the new AWT Plant construction was complete. The Tampa AWT Plant treats waste from a service area with a population of 300,000 and approximately 50 key industries. Industries include breweries, food processors, lead storage battery manufacturing, electroplating, and printed circuit board manufacturing. Most pretreatment programs have involved industrial process changes in place of treatment plants, thus producing little toxic residue. Pilot plants of the AWT process selected for Tampa were run for approximately two years to verify the treatability of the wastewater by the process of choice. Thru planning and industrial cooperation Tampa has maintained a combined wastewater that is compatible with the POTW.

INTRODUCTION

The City of Tampa began the planning stages for a new treatment plant in 1968. During the planning stages a great deal of time was devoted to selecting a process which would insure the treatability of the combined industrial and domestic wastewater. In 1973, before detail design work began, the City ran a pilot plant which represented the treatment process of choice. Also in 1973 a full scale industrial waste monitoring program was funded. The purpose of the industrial waste monitoring section was to develop "User Charge" and "Industrial Cost Recovery" systems dictated by PL 92-500 and also to begin a pretreatment program which would insure proper operation of the wastewater entering the new plant. After the plant was started up in January of 1978 it was clear that the program was a success.

TEXT

DESCRIPTION OF THE TAMPA SERVICE AREA

The City of Tampa has a population of 300,000 with approximately 50 key industries. The City is also headquarters for many firms with dry manufac-

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

turing facilities. Most industry in Tampa produce either no liquid waste or a waste which is compatible with the Publicly Owned Treatment Works (POTW). Tampa industry is best characterized by Table 1.

TABLE 1 TAMPA INDUSTRIAL FLOWS

Industrial Category	MGD
Brewing	1.454
Battery Mfg.	0.102
Metal Platers	0.040
Seafood Processing	0.877
Chemical Mfg.	0.015
Soft Drink Bottling	0.263
Dairy Processing	0.141
Meat Processing	0.053
Aluminum Can Mfg.	0.842
Food Processing	0.165
Power Laundries	0.124
Printed Circuit Board Mfg.	0.300
Misc. Industries	0.050
Total Industrial Flow	4.426

With an industrial flow of 4.4 MGD approximately 1.3 MGD has the potential to contain toxic pollutants which could adversely effect the POTW. Another section of the paper will explain how 0.85 MGD of this total was eliminated from the potentially toxic category. The remaining 70% of the industry in Tampa exerts an organic loading on the plant. The designers, having this information, formulated a plant process which would have maximum flexibility with regard to organic loading.

TREATMENT PLANT PLANNING

Planning for the new POTW in Tampa began in 1968. By 1971, studies were underway to choose the best AWT process for Tampa wastewater. The City was faced with having to remove 90% of the biochemical oxygen demand, suspended solids, nitrogen, and phosphorus. Due to a high soluble BOD in the influent the decision was made to go to a biological system in lieu of the physical chemical system. In 1972, the consultants decided to conduct pilot studies on the treatment process of choice. This process was a two stage activated sludge system using pure oxygen for both carbonaceous and nitrification steps. The system was designed to use alum in the fourth stage carbonaceous reactors for phosphorus removal. Denitrification would take place in down-flow deep bed sand filters using methanol as a carbon source.

In 1973 a pure oxygen pilot plant was moved to the Hookers Point site in Tampa. Pilot studies were conducted for several months with the end result being the basis of design for the new City of Tampa AWT Plant. At this time Federal funding for design and construction was obtained as a result of PL 92-500.

As construction progressed another pilot plant was constructed in the 1976-77 time-frame. This pilot plant would serve not only as a training function but also as a verification of the original design. The pilot ran for over a year and served several purposes. During the year time period we trained many operators on the new process and also tried several alternate carbon sources to methanol in the denitrification process.

INDUSTRIAL WASTE PROGRAM

The Tampa industrial flow was characterized in a previous section. This characterization was due to an extensive industrial waste program which was funded and initiated in 1973 as a result of planning needs. Public Law 92-500 also stated that Industrial User Charge, Industrial Cost Recovery, and Pre-treatment Systems would be required as a prerequisite to Federal funding for a POTW. The industrial waste section was set up with the above requirements in mind. The main purpose of the section was to insure that industry paid for what it discharged and did not discharge any quantity of waste which would be toxic to the POTW. The User Charge and Grant Recovery systems were formulated and written into the ordinance immediately.

Unlike the user charge system, the pretreatment program was more difficult to initiate. Our division took many samples to determine where we stood as far as toxic pollutants were concerned. We considered BOD, SS, N, and P as compatible because the treatment plant was designed to remove these pollutants.

TABLE 2 TYPICAL HEAVY METAL CONCENTRATIONS BEFORE THE PRETREATMENT PROGRAM

Metal	AWT Inf. lbs/day
Cd	10.0
Cr	176.8
Cu	60.0
Pb	110.0
Zn	220.2

Values for other heavy metals were in most cases lower than the ordinance limits. Florida, like most states, does not have adequate hazardous waste disposal facilities. With this in mind we embarked on a different approach to pretreatment. This approach revolved around the idea of "do the best you can to remove the toxics without creating a toxic sludge which will need disposal". Several of our large industries took the lead in this effort.

The aluminum can manufacturers which support the brewing and soft drink industry in Tampa were the first to respond to the concept. Chromium was used in their process as a cleaner and brightener before painting. The chromium rinse was completely eliminated and another process solution was used which contained no toxic pollutants. This process change eliminated 90% of the chromium discharge to the sewer system.

Lead storage battery manufacturers responded with extensive water recycling systems which not only saved on the water bill but also kept concentrated waste streams in the respective production areas. As a result of the water recycling operation the battery plants also have a reclaimable waste in the pasting area of the plant. The end result is that the lead concentration in the raw waste-water has been greatly reduced, with no toxic sludge being produced.

Individual job shop platers have responded by making improvements in housekeeping and rinsing techniques. Most small plating companies have reduced heavy metal levels to a fraction of what they discharged before the program began. Again a great reduction was achieved without creating a sludge which would need disposal. Two plating ships which plate cadimum may still have to install some minor pretreatment processes.

The only industry which has decided to go to a pretreatment system is a printed circuit board manufacturer. This plant is about ready to go on line. The resultant sludge will have to be shipped out of state for proper disposal.

The POTW influent can now be characterized by the following table which expresses present heavy metal levels and sources.

TABLE 3 INFLUENT HEAVY METAL CONTRIBUTIONS LBS/DAY

Metal	AWT Inf.	Industrial Point Sources	Potable Water Supply
Cd	3.0	0.39	0.75
Cr	31.5	3.4	1.13
Cu	34.5	11.8	6.4
Pb	17.3	4.7	5.3
Zn	39.0	6.1	25.9

The same data expressed as percentages from known and unknown sources is expressed in Table 4. It should be noted that even with what we feel is a very accurate industrial survey much of the pollutant load is unidentified.

TABLE 4 PERCENT HEAVY METAL CONTRIBUTION

Metal	Industrial Point Sources	Potable Water Supply	Other Sources
Cd	13	25	62
Cr	11	4	85
Cu	34	19	47
Pb	27	31	42
ZN	16	66	18

The pretreatment program has resulted in heavy metal effluent values which are lower than Florida's strict water quality standards. Concentrations given in Table 5 represent effluent from the AWT Plant before the allowed mixing zone.

TABLE 5 AWT EFFLUENT HEAVY METALS

Metal	AWT Effluent mg/1	Class III Water Quality Standards mg/1
Cd	0.007	0.005
Cr	0.035	No Limit
Cu	0.014	0.015
Pb	0.046	0.03
Zn	0.028	0.03

All of the above results have been obtained thru industry/city cooperation. The significant difference in this and other pretreatment programs is that only a small amount of toxic sludge is produced. Our present pretreatment program is being redesigned to meet all EPA guidelines and pretreatment standards.

AWT PLANT PERFORMANCE DATA

The Hookers Point Advanced Wastewater Treatment Plant was started up on January 28, 1978, almost 10 years after planning began. The plant is designed to treat 60 MGD of combined domestic/industrial wastewater. Due to the high organic load and high soluble BOD the plant was designed to treat shock loads of organic pollutants. The plant influent and design performance is characterized in Table 6.

EPA-287 (Cin.)
(4-76)

TABLE 6 AWT DESIGN CRITERIA

Parameter	Influent mg/l	Effluent mg/l
BOD	224	20
SS	221	20
N	32	3
P	12	1

Since the plant was designed some of the organic loadings have increased. This is due to expansions at the breweries and increased food processing. Plant influent for 1979-80 is characterized in Table 7.

TABLE 7 1979-80 INFLUENT CHARACTERISTICS

Parameter	Influent
BOD	367
SS	267
N	26.4
P	8.9

The plant has achieved much better treatment than the pilot plants would have indicated. State standards have changed since the plant was designed. Advanced wastewater treatment standards now require 5 mg/l BOD, 5 mg/l SS, 3 mg/l total nitrogen and 1 mg/l total phosphorus. The plant is only required to remove 90% of the BOD, SS, N, and P. In June of 1979 the City obtained a variance on the phosphorus removal requirement to a level of 7.5 mg/l. Actual plant performance can be characterized in Table 8.

TABLE 8 ACTUAL PLANT PERFORMANCE

	Plant Data		State Stds.		NPDES Limits
	% Rem	Eff mg/l	% Rem	Eff mg/l	Eff mg/l
BOD	98	5.4	90	5	30
SS	99	2.5	90	5	25
N	91	2.3	90	3	5
P	48	4.6	90	1*	2*

*New variance limit of 7.5 mg/l.

SUMMARY & CONCLUSIONS

Through advanced planning and city/industry cooperation the City of Tampa AWT Plant has performed far better than was anticipated. A different approach to pretreatment has produced excellent results and very little toxic sludge. Again city/industry cooperation was the key to reduced toxic pollutants in the City of Tampa wastewater.

PB83-142406

SOURCES OF TOXIC POLLUTANTS FOUND IN INFLUENTS TO POTW'S

R. Seraydarian
R. Frederick
D. Ehreth
USEPA, Washington, D.C.

ABSTRACT

The purpose of the project was to determine the origin of, and magnitude of, the problem of toxic substances in Publicly Owned Treatment Works (POTW). A major objective of the Monitoring and Data Support Division Study was to determine the relative significance of the major source types - residential, commercial and industrial - in contributing priority toxic pollutants to POTW influents. The collection system from eleven residential areas, ten commercial areas, and five industry-dominated areas in four different cities were sampled. The influent to the POTW and tap water were also sampled. All of the 129 priority pollutants were looked for, but 67 were not found in collection systems of four POTW's. The most prevalent pollutants detected were metals, solvents, and phthalate ester plasticizers. Industrial sources appear to dominate the loading on the POTW for most pollutants, while residential and commercial contributions are still important for some pollutants, although at a lower total loading when industrial sources are not present. The type and size of industry present was a significant factor in detecting the presence and concentration levels of the priority pollutants.

INTRODUCTION

Congress significantly amended the Federal Water Pollution Control Act by the Clean Water Act of 1977 (CWA), largely as a result of national emphasis on controlling toxic pollutants. Toxic water pollutants, also called priority pollutants, include at least 65 listed toxic substances and categories of substances resulting from the 1976 suit by the Natural Resources Defense Council (NRDC) and others. The list of 65 was later alternatively defined as 129 specific inorganic and organic compounds. The Environmental Protection Agency has developed a comprehensive program to promulgate guidelines to control the 129 toxic substances in industrial effluents. EPA is also developing a strategy for controlling toxic pollutants in urban systems.

EPA's Office of Water Planning and Standards (OWPS) was given the responsibility to develop a comprehensive regulatory strategy for toxic pollutants in urban systems. Development of the strategy requires the assessment of the magnitude of the toxic pollutant problem in sewage treatment plants, characterization of the fate of the toxic pollutants in treatment plants, and determination of the sources of these toxic poutants into POTW's. Knowledge of the presence or absence of toxic pollutants and their sources is essential to an effective pretreatment program as well as to an overall urban control strategy.

This paper reports the result of a study to determine the relative significance of the major source categories - residential vs. commercial vs. industrial - in loadings to POTW influents.

A POTW service area in each of four cities was monitored for the priority pollutants. In each city, specific sampling sites were selected to represent each of the major source categories. In total, 11 residential, 10 commercial, and 5 industrial sites were sampled in addition to the tap water and POTW influents.

OBJECTIVES OF THE SOURCE STUDY

The program had several major objectives: 1) to generate a small data base for use in addressing a set of questions concerning priority pollutants in POTW's:

- Which of the pollutants were present in each source category (and which were not)?
- What is the frequency and relative mass loadings contributed by each source for each pollutant?
- What effect does degree of industrialization have on POTW influent concentrations?
- Can the mass loading indices from various sources be used to effectively predict the influent concentrations to the POTW?

2) To provide some information about the reliability of the analytical data generated. This objective has been achieved by establishing a substantial quality assurance/quality control program.

CITY SELECTION

The cities selected for the project monitoring program were a subset of the 40 cities selected by the Office of Water Planning and Standards (OWPS) for study under the program to determine the fate of the priority pollutants in POTW's. Three major constraints were imposed upon the 40 POTW's selected for monitoring:

1) Only those plants employing secondary or better treatment technology were to be considered;
2) Only plants with average daily influent flows greater than or equal to 5.0 MGD were to be considered; and
3) Only those treatment facilities located within standard metropolitan statistical areas (SMSA's) were to be considered.

However, selection of the four cities to be included in the source study required consideration of a number of other factors regarding the size of the service area and sampling logistics.

Plant and basin size were important considerations because each appeared to have a bearing upon the diversity of socio-economic activity that existed within an area. As was learned early in this program, plants with small daily influent flows (5 to 10 MGD) were frequently located in areas where only one type of activity was present. For example, many of the basins that exhibited low influent rates (5-10 MGD) were comprised of virtually all (90-95%) residential activity, with very little (5-10%) commercial activity and almost no industrial component (0-1%). Conversely, one plant with an average daily influent of 12 MGD had a flow mix which was nearly 99% industrial. Any of these plants would have been acceptable if the project's goals were only to assess one source's contributions independent of the others; but inasmuch as an assessment of all three was desired concurrently, these types of sites were excluded from further consideration. We expect to pursue this approach to confirm our indices as the project progresses.

A second problem encountered in several of the smaller basins (with respect to the area of land drained) was that even when a basin was identified which contained all three activities (residential, commercial and industrial), it was frequently impossible to isolate these activities in the collection system. This difficulty usually developed because the smaller basins were frequently interconnected by single interceptors, where wastewater from one activity would drain through another, prior to reaching the POTW.

The identification of proper sampling zones was also considered to be important. Since the final goal of this study was to enumerate the pollution burden of at least two socio-economic activities at a minimum in each basin, areas typifying both of these had to be identified, and segregated if possible. It was desirable to locate duplicate areas within a basin because this allowed for an immediate confirmation of results under conditions that were equivalent.

Another factor considered important to the selection of a candidate facility related to the availability of background or supportive data. Of particular importance was the availability of demographic information which is needed to describe the activity within the particular sampling zones selected and within the basin as a whole. However, supplementary data, such as 201 and 208 studies, facility plans, and inflow/infiltration assessment were also available.

EPA-287 (Cin.)
(4-76)

Similarly, it was essential that the identified facility have detailed maps of the collection system. Without having access to these maps, it is virtually impossible to select appropriate sampling locations because the area drained cannot be outlined.

The geographic location of the facility was also used as a criterion in the selection process. Although one reason for including this issue pertained to the climate of the area during the analysis period, the main reason for considering it related to the issues of the possible variability of groundwater and soil chemistry across the country. Other factors considered included congestion of the sample site areas, the accessibility of a major airport, and the availability of rental vehicles and supplies.

The willingness of the local authorities to participate and cooperate in the study was also a prime consideration in city selection.

The four cities were selected sequentially based on the results of the prior cities. Table 1 summarizes the geographical and service area information for the four cities.

SAMPLE COLLECTION

All sampling consisted of grab samples taken at each site every 3-4 hours and composited over a 24- or 48-hour period. Automatic samplers were not used because of the difficulty in obtaining volatile samples with the automatic equipment installed in the manhole. Actual collection was completed using a two-liter stainless steel graduate (bucket) and a telescopic pole (extended length of 9.75 meters). Normally the first aliquot obtained was used to determine pH, temperature and to determine whether oxidizing species were present (by means of a potassium-iodide, starch indicating paper test). This volume was then discarded and additional aliquots were obtained to fill a predetermined number of sample bottles. Prior to leaving a site to move onto the next site, an instantaneous flow measurement was made and the results recorded. These flow measurements were used in the laboratory to flow composite all appropriate increments into the final sample for chemical analysis.

TABLE 1. SUMMARY OF CITIES SELECTED

Geographical Location	Size of Service Area	POTW Flow	% Industry (1)(by flow)	Res. Sites	Comm. Sites	Ind. Sites
City A Midwest	29 sq. miles	10 MGD	1%	2	2	0
City B Midwest	36 sq. miles	24 MGD	12%	3	2	2
City C Southwest	140 sq. miles	80 MGD	18%	2	3	3
City D Northeast	65 sq. miles	40 MGD	7%	4	3	0
			TOTAL	11	10	5

Flow measurements were initually obtained using a depth of flow/Manning equation approach. In practice, the measured depth of water contained within a pipe can be used to determine the rate of water flow, if certain physical parameters of the pipe (pipe diameter, slope, and roughness coefficient) are also known. However, subsequent to the first area studied, the accuracy of this approach was questioned because values obtained appeared to be unexplainably high. Similar observations were also obtained in the next two cities, but in these instances confirmation that the measured flows were too high was obtained by the results of theoretical flow balances.

The theoretical analysis was based on the assumption that the residential contribution to the basin flow was 100 gallons per day per person, and that all other activities (commercial, industrial, municipal, etc.) discharged as much as they consumed. By obtaining the water billing records of the area, it was possible to estimate a dry weather flow throughout a basin or for any individual site.

As a result of these theoretical analyses, additional flow measurement procedures were evaluated during the fourth city study. Included among the alternative procedures were a direct velocity determination/depth of flow approach, a Palmer-Bowles flume/Manning dipper approach and a Palmer-Bowles flume/Manning equation approach.

The results of this study indicated that either of the first approaches produced more reliable estimates of the actual flow rate than did the depth of flow/Manning equation technique. However, the flume/Manning dipper technique was somewhat more difficult to implement due to the additional effort required to install both the flumes and the dippers. Therefore, the velocity/depth of flow method was used to correct or recalibrate all depth of flow/Manning equation results that had been obtained from the first three city studies. The flow data used for the analyses in this report are all based on the velocity measured (or corrected) flow for each sampling site.

QUALITY ASSURANCE/QUALITY CONTROL

A substantial quality assurance/quality control program was incorporated into the sources investigation in order to document the reliability of the data obtained. This quality assurance/quality control (QA/QC) program required certain of the samples taken in the field to be put through a procedure which determines recoverability of each pollutant, reproducibility of the analytical results, and a check for laboratory or field contamination.[1] The POTW program was essentially a screening process. Yet, reproducible, accurate data were also needed rather than approximate quantitative data. For the QC samples, a total of 121 priority pollutants were added into duplicate field samples and into "clean" water samples (method reference standards). Further, since the concentration levels were unknown, all priority pollutants were added into samples blind, rather than basing the levels on the concentration levels found in the field samples. Figure 1 presents the five aliquots associated with a QC sample. Initially 30 percent of the samples were chosen as QC samples. The samples were chosen to represent a range of sample matrices. Field blanks, calibration standards, and instrument performance check standards were analyzed routinely.

It was also necessary for all analysts previously not using the procedure to practice by analyzing method reference standards. Satisfactory performance had to be demonstrated before proceeding with the analysis of any field samples. Procedures in the EPA Screening protocol were detailed and distributed to all analysts before analyzing any samples.

The emphasis in the POTW QA/QC program was to obtain data on all the priority pollutants and not just those known to be present in the field samples, thereby providing a basis for understanding the behavior of all priority pollutants when using the EPA Screening Protocol and decreasing the number of false positive or false negative results.

An additional feature of the POTW QA/QC program was the use of "total method" internal standards. The use of these internal standards was initiated with the samples for the third city. Four "total method" internal standards were added to the aqueous samples for the Acid and Base/Neutral analyses. Figure 2 summarizes the sampling and spiking procedures for each QA sample. The precision and accuracy data obtained for these standards provided an efficient and cost effective means for monitoring the quality of priority pollutant data being obtained on each and every sample (field and QC) analyzed. It must be recognized that the use of these standards does not replace the QC sample to which all the priority pollutants were added. Each pollutant has its own chemistry and may present problems in a particular type of sample matrix. Therefore, QC samples (A,B,C,D,F) were still analyzed over a range of sample matrices, in order to check the behavior of all priority pollutants with respect to the various matrices.

A summary of the recovery data is summarized in Table 2. Recoverabilities averaged between 77% and 100% with a standard deviation of 7% to 26%. The overall precision for the priority pollutants improved throughout the program, due in part to increased familiarity with the analytical procedures. However, the overall improvement was also due to special attention given to the data. The analytical laboratory (Arthur D. Little, Inc.) continually modified the EPA procedures, resulting in a higher quality of data.[3]

RESULTS AND DISCUSSION

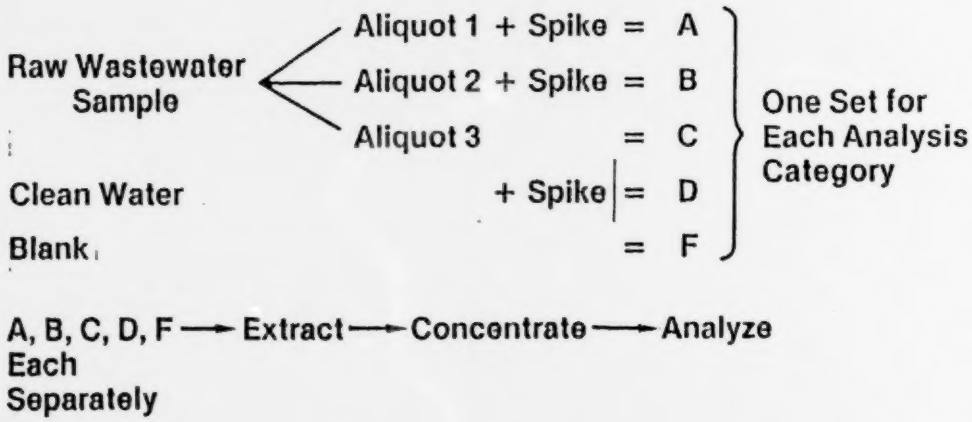
The most important result from this study is that relatively few priority pollutants were found in the sources. Table 3 lists those 67 pollutants that were never detected in any of the samples. Many of the pollutants were detected at low concentrations and were observed infrequently. Figures 3 through 7 summarize the average frequency and concentration levels for the priority pollutants detected more than 50% of the time and at average concentration greater than 10 ug/L in tap water, residential, commercial, and industrial areas, and the POTW influent. The data has been grouped according to those chemicals observed at levels less than 10 ug/L, 10-100 ug/L, and at levels greater than 100 ug/L. The increase in both number and concentration of priority pollutants is observed as one progresses from tap water through residential and commercial sources to the industrial sources. However, it is necessary to compare masses if one is to be able to quantify loadings from each source.

EPA-287 (Cin.)
(4-78)

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

FIGURE 1

DESCRIPTION OF QUALITY CONTROL SAMPLES


Raw Wastewater Sample
Aliquot 1 + Spike = A
Aliquot 2 + Spike = B
Aliquot 3 = C
Clean Water + Spike = D
Blank = F
One Set for Each Analysis Category
A, B, C, D, F Each Separately → Extract → Concentrate → Analyze

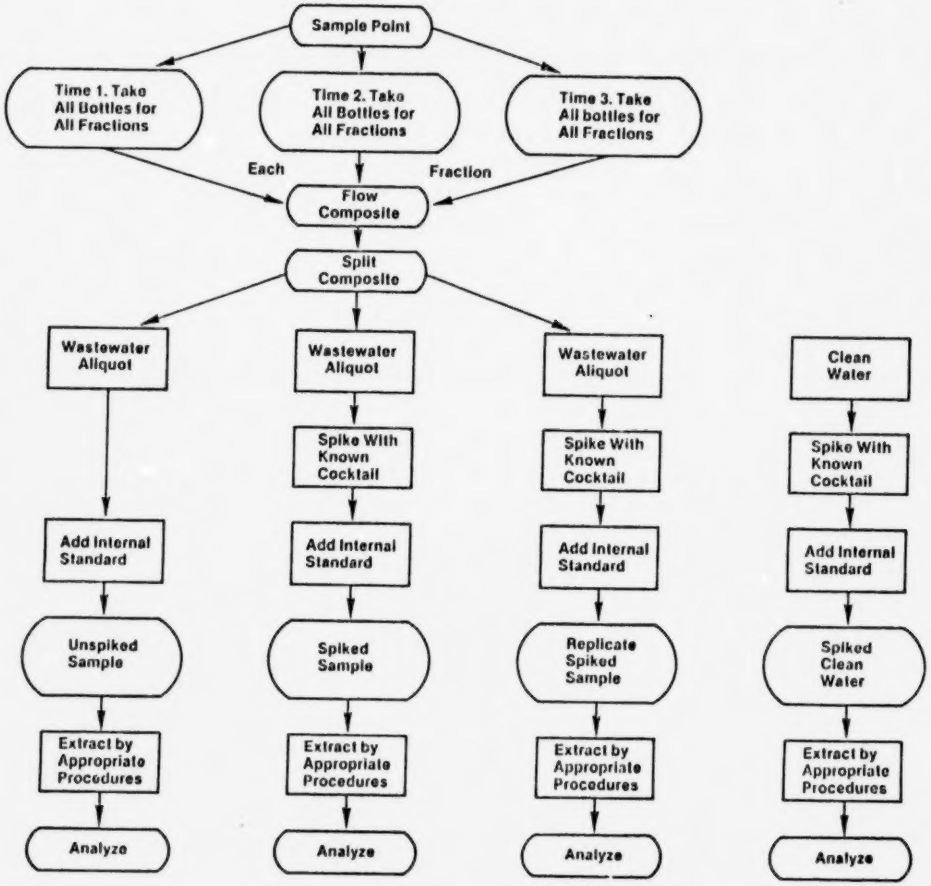
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA (OUTSIDE DIMENSION) FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
DROPPED HEAD BEGIN SECTIC HERE
CENTER OF PAGE
TOP OF IMAGE AREA

FIGURE 2

QA SAMPLE SCHEMATIC


Sample Point
Time 1. Take All Bottles for All Fractions
Time 2. Take All Bottles for All Fractions
Time 3. Take All bottles for All Fractions
Each
Fraction
Flow Composite
Split Composite
Wastewater Aliquot
Wastewater Aliquot
Wastewater Aliquot
Clean Water
Spike With Known Cocktail
Spike With Known Cocktail
Spike With Known Cocktail
Add Internal Standard
Add Internal Standard
Add Internal Standard
Add Internal Standard
Unspiked Sample
Spiked Sample
Replicate Spiked Sample
Spiked Clean Water
Extract by Appropriate Procedures
Extract by Appropriate Procedures
Extract by Appropriate Procedures
Extract by Appropriate Procedures
Analyze
Analyze
Analyze
Analyze

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

Analysis of the summarized data for each collection system studied showed that for City A (about 1% industrial) the residential sources dominate the mass flow to the POTW. For City B (12% industrial) residential sources are a significant percentage of the loading, but many pollutants are dominated by the industrial flow. For City C (18% industrial) the analysis shows a clear dominance of mass loadings from industrial sources. For those situations where little industrial contributions exist, the total loading to the POTW is significantly lower than when industry is also contributing to the POTW.

Tap water contributed primarily trihalomethanes and copper. Residential sources had high zinc, copper and manganese levels, plus some other metals. Concentration levels for most pollutants, especially metals, appear to be substantially higher from old residential areas compared to newer residential areas, but the presence and frequency of pollutants did not vary significantly. Commercial sources were quite similar to residential sources, but did have some additional pollutants and a few more metals. Table 4 summarizes the overall average concentrations for the 11 residential and 10 commercial areas. The industrial sources had high concentrations of many of the detected organic pollutants and all of the observed metals were present in this source category.

TABLE 2. CHEMICAL ANALYSIS ACCURACY AND PRECISION SUMMARY FOR ALL 4 CITIES

Analysis Category	Method Reference Standard* Average Recovery	Method Reference Standard* Average Std Deviation	Raw Wastewater Average Recovery	Raw Wastewater Avg Std Deviation
Volatiles	92	18	88	23
Acids	79	16	88	16
Base/Neutrals	79	21	72	19
Pesticides and PCB's	77	14	75	15
Total Cyanides	96	8	91	12
Total Phenols	97	7	96	11
Metals	100	26	94	18
Classical Parameters	81	14	--	--

*Standards spiked into pure distilled water.

In order to characterize the major sources, it was attempted to develop mass loading indices for each priority pollutant detected. These indices could prove useful in predicting the POTW influent concentrations for a specific service area. They would also provide general background levels for analysis of the effectiveness of various industrial pretreatment alternatives; i.e., they might be used to predict if the reduced loading at the industrial plant would be adequate to protect the POTW and sludge quality.

Because of the large variability in the presence and concentration levels from various industrial sources, it does not seem valid to develop overall indices to characterize industrial areas. However, if the specific industries discharging to a POTW can be identified, industrial effluent monitoring data will be available to estimate the priority pollutant levels from each industry.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-75)

TABLE 3. POLLUTANTS (67 TOTAL) NEVER DETECTED IN FOUR CITIES

101	Chloromethane
102	Dichlorodifluoromethane
103	Bromomethane
107	Acrolein
122	Cis-1,3-dichloropropylene
202	Nitrophenol
208	2,4-dinitrophenol
209	4,6-dinitro-2-cresol
211	4-Nitrophenol
304	Hexachloroethane
305	Bis(chloromethyl)ether
306	Bis(2-chloroethyl)ether
307	Bis(2-chloroisopropyl)ether
308	N-Nitrosodimethylamine
309	Nitrosodi-n-propylamine
311	Hexachlorobutadiene
313	2-Chloroethyl vinyl ether
314	Bis(2-chloroethoxy)methane
316	Isophorone
317	Hexachlorocyclopentadiene
318	2-Chloronaphthalene
319	Acenaphthylene
320	Acenaphthene
321	Dimethyl phthalate
322	2,6-Dinitrotoluene
323	4-Chlorophenyl phenyl ether
324	Fluorene
325	2,4-Dinitrotoluene
327	1,2-Diphenylhydrazine
328	N-Nitrosodiphenylamine
329	Hexachlorobenzene
330	4-Bromophenyl phenyl ether
336	Benzidine
340	Chrysene/Benzo(a) anthracene
342	3,3'-Dichlorobenzidine
343	Benzofluoranthenes*
345	Benzo(a)pyrene
346	Indeno (1,2,3-c,d)pyrene
347	Dibenzo(a,h)Anthracene
348	Benzo(g,h,i)perylene
349	TCDD
401	alpha-BHC
402	gamma-BHC
403	beta-BHC
405	delta-BHC
407	Heptachlor epoxide
408	Endosulian I
409	DDE
410	Dieldrin
411	Endrin
412	DDD
413	Endosulfan II
414	DDT
415	Endrin aldehyde
416	Endosulfan sulfate
417	Chlordane
418	Toxaphene
419	PCB-1221
420	PCB-1232
421	PCB-1242
422	PCB-1248
423	PCB-1254
424	PCB-1260
425	PCB-1016
503	Beryllium

*Two compounds

For the residential areas, we attempted to use the population as an index basis. Thus, for the residential sites, a per capita discharge rate might be calculated as follows:

$$\text{mass/person/day} = \frac{\text{concentration x flow}}{\text{population}}$$

For reporting convenience, the residential values have been developed in units of mg/person/day. The total service area residential contribution may thus be estimated as:

$$\text{RES(kg/day)} = \text{Res. Ave. (mg/person/day) x Population x } 10^{-6}$$

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

TABLE 4. OVERALL SOURCE AVERAGE CONCENTRATIONS

Pollutant		ug/L* Res.	ug/L* Com.
110	1,1-Dichloroethylene	.0	.3
111	1,1-Dichlorethane	.0	.1
112	Trans-1,2-Dichloroethylene	.0	1.5
113	Chloroform	3.0	6.7
114	1,2-Dichloroethane	.1	.1
115	1,1,1-Trichloroethane	2.3	2.9
116	Carbon Tetrachloride	.0	.1
117	Bromodichloromethane	.0	1.0
120	Trichloroethylene	.4	12.8
121	Benzene	.2	2.7
123	Dibromochloromethane	.0	.7
125	Bromoform	.0	.0
127	1,1,2,2-Tetrachloroethylen	6.3	21.4
128	Toluene	2.6	11.0
129	Chloobenzene	.1	.0
130	Ethyl Benzene	.4	3.0
203	Phenol	5.8	4.5
204	2,4-Dimethylphenol	.7	.0
210	Pentachlorophenol	1.2	5.8
301	Dichlorobenzenes	2.8	7.5
315	Naphthalene	2.1	2.6
326	Diethyl Phthalate	9.8	5.7
333	Di-n-butyl Phthalate	9.0	11.7
337	Butyl Benzyl Phthalate	6.8	10.6
338	Bis(2-Ethylhexyl)Phthalate	6.8	7.7
501	Antimony	2.7	.3
502	Arsenic	4.8	2.6
504	Cadmium	1.8	.6
505	Chromium	16.3	56.8
506	Copper	72.1	54.5
507	Lead	97.3	49.8
508	Manganese	153.0	224.8
509	Mercury	.4	.4
510	Nickel	4.2	12.4
511	Selenium	3.8	3.3
512	Silver	2.2	2.9
513	Thallium	.0	.1
514	Zinc	214.0	138.1
601	Total Cyanides	1.1	.2
602	Total Phenols	30.8	10.7
703	Ammonia	14.2	10.7
704	Oil and Grease	77.4	109.0
705	TSS	156.8	122.4
706	TOC	81	106.2
707	COD	263.8	346.0
708	BOD	113.9	160.0

*Classicals in mg/L

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER
EPA-287 (Cin.) (4-76)

	Less Than 50%	Greater Than 50%
Greater Than 100 μg/L		
Between 10 μg/L and 100 μg/L	Lead	Chloroform Zinc Copper
Less Than 10 μg/L		Bromodichloromethane Dibromochloromethane Manganese

Figure 3.

Concentration/Frequency of Occurrence: Tap Water

EPA-237 (Cin.)

	Less Than 50%	Greater Than 50%
Greater Than 100 µg/L		Zinc Manganese
Between 10 µg/L and 100 µg/L		Lead Copper Chromium Total Phenols
Less Than 10 µg/L		Chloroform 1,1,2,2-Tetrachloroethylene Toluene Nickel Selenium

Figure 4.

Concentration/Frequency of Occurrence: Residential

EPA-287 (Cin.)
(6-78)

	Less Than 50%	Greater Than 50%
Greater Than 100 µg/L		Manganese Zinc
Between 10 µg/L and 100 µg/L	Trichloroethylene Di-n-butylphthalate	1,1,2,2-Tetrachloroethylene Toluene Butylbenzylphthalate Copper Lead Chromium Nickel Total Phenols
Less Than 10 µg/L		Chloroform Bromodichloromethane 1,1,1-Trichloroethane Benzene Ethylbenzene Silver

Figure 5.

Concentration/Frequency of Occurrence: Commercial

	Less Than 50%	Greater Than 50%
Greater Than 100 μg/L		Ethylbenzene Phenol Dichlorobenzenes Silver Copper Nickel Chromium Lead Manganese Zinc Total Phenols
Between 10 μg/L and 100 μg/L	1,1-Dichloroethylene Trans-1,2-dichloroethylene Carbon Tetrachloride 2,4-Dimethylphenol Pentachlorophenol Bis(2-ethylhexyl)phthalate Cadmium	Chloroform Trichloroethylene 1,1,1-Trichloroethane 1,1,2,2-Tetrachloroethylene Toluene Naphthalene Di-n-butylphthalate Total Cyanides
Less Than 10 μg/L		Benzene Bromodichloromethane Dibromochloromethane

Figure 6.

Concentration/Frequency of Occurrence: Industrial

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD, BEGIN SECTIONS HERE

	Less Than 50%	Greater Than 50%
Greater Than 100 µg/L		Chromium Manganese Zinc
Between 10 µg/L and 100 µg/L	Naphthalene Butylbenzylphthalate Antimony	Trichloroethylene 1,1,1-Trichloroethane 1,1,2,2-Tetrachloroethylene Toluene Ethylbenzene Dichlorobenzenes Copper Lead Nickel Total Cyanides Total Phenols
Less Than 10 µg/L		Chloroform Benzene Diethylphthalate Di-n-butylphthalate Cadmium Silver

Figure 7.

Concentration/Frequency of Occurrence: POTW Influent

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
EPA-287 (Cin.)
(4-76)

For the commercial sites, the only index reliably available for all of the sites studies is the total flow. Thus, for these sources' types, an average concentration value has been calculated so that, when the average value is multiplied by the total basin source type flow, the total source contribution value has been calculated so that, when the average value is multiplied by the total basin source type flow, the total source contribution is obtained:

COM (Kg/day) = [Avg. Com. Conc.(ug/L)] x [Com. Flow(Lps)] x 8.64 X 10-5.

In order to evaluate the potential impact of the various sources on the POTW influent, the above indices were used to calculate the projected POTW loadings for several hypothetical situations. Table 5 shows the fraction contributed from each source type for a city with the following characteristics:

POTW Flow - 1,000 Lps
Residential Flow - 500 Lps
Residential population-114,000 People
Commercial Flow - 200 Lps
Industrial Flow - 300 Lps

The industrial flow was used with an overall industrial index calculated for the 4 cities sampled to estimate the industrial loading. The hypothetical city with 30% industrial flow shows a clear domination by industrial sources for all but a few of the priority pollutants.

OWPS is presently attempting to verify these indices by comparing the predicted POTW influent loadings with actual influent loadings for cities that have been monitored for priority pollutants under other EPA studies.

EPA-287 (Cin.)
(4-76)

TABLE 5. RELATIVE SOURCE STRENGTH COMPARISON

		Fraction			Sum
		Res.	Com.	Ind.	Kg/day*
110	1,1-Diceloroethylene	.00	.02	.98	.30
111	1,1-Diceloroethane	.00	.03	.97	.04
112	Trans-1,2-Dichloroethylene	.00	.08	.92	.33
113	Chloroform	.34	.18	.48	.65
114	1,2-Dichloroethane	.08	.12	.80	.02
115	1,1,1-Trichloroethane	.03	.02	.95	2.32
116	Carbon Tetrachloride	.00	.00	1.00	.74
117	Bromodichloromethane	.06	.28	.67	.06
120	Trichloroethylene	.06	.24	.70	.94
121	Benzene	.15	.50	.35	.09
123	Dibromochloromethane	.05	.28	.67	.04
125	Bromoform	.00	.00	.00	.00
127	1,1,2,2-Tetrachloroethylen	.18	.14	.68	2.66
128	Toluene	.12	.11	.77	1.76
129	Chlorobenzene	.17	.02	.81	.03
130	Ethyl Benzene	.01	.02	.97	2.69
203	Phenol	.17	.02	.82	4.31
204	2,4-Dimethylphenol	.02	.00	.98	1.96
210	Pentachlorophenol	.35	.18	.47	.55
301	Dichlorobenzenes	.02	.01	.97	10.05
315	Naphthalene	.05	.03	.92	1.43
326	Diethyl Phthalate	.93	.07	.00	1.44
333	Di-n-butyl Phthalate	.34	.07	.59	2.95
337	Butyl Benzyl Phthalate	.12	.04	.85	5.15
338	Bis(2-Ethylhexyl)Phthalate	.32	.07	.61	1.84
501	Antimony	.83	.02	.15	.29
502	Arsenic	.86	.05	.09	.94
504	Cadmium	.07	.02	.91	.59
505	Chromium	.06	.05	.89	20.80
506	Copper	.63	.08	.29	11.23
507	Lead	.32	.06	.61	13.66
508	Manganese	.55	.18	.27	21.97
509	Mercury	.34	.08	.58	.08
510	Nickel	.09	.06	.85	3.33
511	Selenium	.83	.12	.05	.46
512	Silver	.06	.01	.93	4.20
513	Thallium	.00	.49	.51	.00
514	Zinc	.35	.06	.59	37.81
601	Total Cyanides	.06	.00	.94	2.51
602	Total Phenols	.33	.07	.59	8.91
703	Ammonia	.77	.09	.14	2.02
704	Oil and Grease	.53	.19	.28	9.81
705	TSS	.66	.09	.25	22.65
706	TOC	.59	.14	.26	12.85
707	COD	.57	.13	.30	46.05
708	BOD	.56	.14	.29	19.21

*Classicals in 10^3 kg/day

REFERENCES

1. U.S. EPA, "Quality Assurance Program for the Analyses of Chemical Constituents in Environmental Samples," Environmental Monitoring and Support Lab., Cincinnati, Ohio, March 1978.

2. U.S. EPA, "Sampling and Analysis Procedures for Screening of Industrial Effluents for Priority Pollutants, EMSL, Cincinnati, Ohio, March 1977, revised April 1977.

3. Arthur D. Little, Inc., Summary of QA/QC Experience on POTW Sources Program, EPA Contract No. 68-01-3857, February 1980, (unpublished).

4. Arthur D. Little, Inc., Report No. ADL 81099-63, Sources of Toxic Pollutants Found in Influents to Sewage Treatment Plants, Contract No. 68-01-3857, October 1979, (unpublished).

5. Callahan, Michael, A., And Ehreth, Donald J., Sources of Toxic Pollutants Found in Influent to Sewage Treatment Plants, March 1979.

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE

PB83-142414

TREATMENT AND REMOVAL OF PRIORITY INDUSTRIAL POLLUTANTS AT PUBLICLY OWNED TREATMENT WORKS

H. D. Feiler
P. J. Storch
Burns and Roe Industrial Services Corporation
P.O. Box 663
Paramus, New Jersey 07652

A. Shattuck
U.S. Environmental Protection Agency
401 M. Street S.W.
Washington, D.C. 20460

ABSTRACT

The U.S. Environmental Protection Agency has initiated a program to study the fate of priority pollutants in 40 POTW's distributed across the United States. Thus far, 20 POTW's have been sampled and data from nine plants has been obtained. The nine plants' data have been summarized and evaluated. Mechanisms for priority pollutant treatment and removal and the impact of industrial flow on POTW influent toxic pollutant concentrations are discussed. Removal efficiencies and approximate calculations of "consistent removals" are presented. Finally, concentration factors for priority pollutants in POTW sludges and mass balances were calculated and are presented.

INTRODUCTION

In 1978, the United States Environmental Protection Agency (EPA) embarked upon a program of study designed to elucidate the occurrence and fate of 129 selected toxic organic and inorganic pollutants (priority pollutants) in Publicly Owned Treatment Works (POTW's). The scope of this project includes week-long, round-the-clock sampling at 40 POTW's across the United States. Samples collected are subsequently analyzed for the priority pollutants as well as conventional and selected non-conventional parameters. Currently, 20 POTW's have been sampled and data for 9 plants have been reported and evaluated. In this paper, data summaries for these first nine plants are presented. Specific phenomena regarding the fate of these pollutants in POTW's will also be discussed.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

Additionally, the impact of industrial contributors on toxic pollutant incidence in raw wastewater and POTW ability to treat or remove these pollutants are covered. Finally, a hypothetical analysis of the possible revision of categorical pretreatment limitations based on incidental removal or treatment in the POTW is presented.

Treatment and Removal of Toxic Pollutants in POTW's

In evaluating the fate of toxic pollutants in POTW's, it is useful to highlight the contrast between the terms "removal" and "treatment," which are often used interchangeably. This is improper since removal and treatment refer to different types of phenomena. For a pollutant to be treated, it must be eliminated completely. That is, the pollutant's physical form is changed such that the material is no longer an environmental concern. Conversely, removal only implies pollutant transfer. Specifically, the removed pollutant is transferred from the waste stream in question to a location which may or may not be more environmentally acceptable. For example, biodegradable pollutants are treated in POTW's, whereas metallic pollutants, which are chemical elements, are not changed but only removed, concentrating in POTW sludge streams.

Removal or treatment of toxic pollutants in a POTW can occur as a result of various physical, chemical or biological processes that take place within the treatment system. The exact combination of these phenomena affecting any particular priority pollutant depends largely on the nature of the pollutant itself, and the POTW unit operations applied to that pollutant.

Physical mechanisms fall into three broad categories: removal as a solid with other suspended solids, adsorption onto suspended solids with subsequent removal, and atmospheric stripping. Removal of toxic pollutants with suspended solids in primary sludge is most prevalent for the heavy metals. Combination of the heavy metals with alkalinity or sulfide will produce insoluble species that settle out of raw sewage simultaneously with other wastewater solids.

Adsorption onto solid surfaces provides an additional removal mechanism for some organic priority pollutants. If an organic material is insoluble in water, slightly soluble or hydrophobic, the organic pollutant may preferentially adsorb on solid surfaces. In raw sewage, both suspended solids and floatables (greases) may be available for sorption. Therefore, when scum or primary sludge is removed, organic priority pollutants, which may be concentrated in these materials, may also be removed.

A significant proportion of the organic priority pollutants is relatively volatile. It has been postulated that during aeration some of these materials may be air stripped and subsequently released to the atmosphere. This phenomena might account for some observed removals of biologically refractory volatile organics, especially aromatic species, in activated sludge plants.

Chemical treatment of toxic pollutants generally is applicable to organic materials which may come in contact with strong oxidants in the POTW. Most commonly, chlorine used for disinfection or odor control reacts with organic pollutants. At times, the organic species are simply chlorinated, sometimes creating toxic materials. However, treatment may occur when the oxidation of the organic material goes to completion, destroying the toxic pollutant and forming carbon dioxide and water. Chlorine is not the only oxidant used within a POTW which could destroy organic pollutants. Hydrogen peroxide, which is sometimes used to control filamentous bulking, or ozone, which is gaining acceptance as a disinfectant, can also provide beneficial oxidation and destruction of organic pollutants. Oxygen from aeration processes may also contribute to the oxidation of some materials.

Under the proper conditions, organic toxic pollutants may be biologically treated by acting as substrate for organisms in the treatment plant's biomass. Aliphatic compounds are generally more amenable to breakdown in biological systems than aromatic compounds, straight chain aliphatics being most easily degraded. In order for an organic pollutant to compete as a food source with normal organic constituents in sewage (carbohydrates, proteins, fatty acids, etc.), certain conditions should be maintained, such as acclimation to the possible toxic effects of the pollutant. If these conditions can be met, significant removal by biodegradation can occur.

A sometimes overlooked mechanism for the removal of inorganic priority pollutants via biological processes is the uptake of trace quantities of these pollutants as micronutrients. These materials may find their way into the biomass as a result of being complexed and incapsulated in a material that is consumed by cells.

POTW Selection

Presently, about 20 plants have been sampled as part of the 40 plant POTW program. The goal of the project is to obtain priority pollutant data representative of major POTW characteristics as are currently common in the United States. Table 1 presents the characteristics of the nine plants covered in this paper.

Primary factors considered in selecting the plants included:

- Treatment processes
- POTW size
- Amount of industrial contribution
- Type of industrial contribution
- POTW operating efficiency
- Operation as a percent of design capacity
- POTW location representing all EPA regions

The plants selected have been and will represent the full spectrum of common treatment processes in use today. However, since activated sludge and trickling filter plants are most prevalent, the 40 plants will be heavily weighted with those types. POTW size is measured by design flow. Because the General Pretreatment Regulations (40CFR 403) generally affects only

EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET

BEGIN FIRST LINE OF TEXT HERE

DROPPED HEAD. BEGIN SECTIONS HERE

CENTER OF PAGE

TOP OF IMAGE AREA

TABLE 1 POTW CHARACTERISTICS

	Plant								
	1	2	3	4	5	6	7	8	9
Treatment Process	Conv. AS	Conv. AS	AS	Conv. AS	AS	Contact Stab.,AS	AS	AS + TF	Conv. AS
Design Flow, MGD	120	15	14	120	25	7.4	66	50	60
Avg. Flow MGD	90	7	10-11	80-85	19	6	50	20-25	45
% Ind. Contrib.	30	2	10	8	10-15	26	15	11	9
BOD Inf/Eff	237/20	89/15	185/23	207/40	219/21	230/25	110/10	168/10	125/9
TSS Inf/Eff	254/27	155/22	120/20	180/70	170/29	290/30	130/15	256/15	137/14
Major Industrial Contrib.	Pharm., Petro-chemical, Plating, Found. Coking, Foods	Grain Stg., Oil/Fuel Term., Machine Tools, Metalwk.	Chicken Process, Plastics, Textiles	Beverages, Plating, Paint&Ink, Chemicals, Foods, Paper, Photo Process.	Auto Mfg. Hospitals, Plating, Paper, Photo Process.	Plastics & Syn. Found., Bakery	Plating Auto Pts. Furn.	Auto Mfg.	NA

BEGIN LAST LINE OF TEXT

3/8"

BOTTOM OF IMAGE AREA (LENGTH OF DIMENSION FOR TABLES AND ILLUSTRATIONS)

PAGE ___ SEE

EPA-287 (Cin.)
(4-76)

TABLE 2 SUMMARY OF ANALYTICAL DATA

PLANT 1

FRACTION	PARAMETER	UNITS	INFLUENT	EFFLUENT PRE CL.	FINAL EFFLUENT	PCNT REM.	PRIMARY SLUDGE	WASTE ACT. SLUDGE	FLOT-ABLES
CONVENTIONALS	BOD	MG/L	215	22	13	94	20167	6033	0
	TOTAL SUSP. SOLIDS	MG/L	175	10	20	89	46667	6300	0
	COD	MG/L	423	69	68	84	57500	6717	0
	OIL : GREASE	MG/L	50	NOT RUN	5	90	8060	373	L 0
NON-CONVENTIONALS	TOTAL PHENOLS	UG/L	150	NOT RUN	13	91	672	30	L 0
	TOTAL SOLIDS	MG/L	939	835	834	11	56667	6030	1
	TOTAL VOLATILE SOLIDS	MG/L	252	130	262		26833	3293	1
	TOTAL VOL. SUS. SOLIDS	MG/L	113	8	14	88	23333	4200	0
	AMMONIA NITROGEN	MG/L	7	31	5	29	59	9	1
	TOC	MG/L	205	55	65	68	23500	2717	0
VOLATILES	ACRYLONITRILE	UG/L	L 100	L 100	L 100		L 100	3	L 0
	BENZENE	UG/L	143	1	3	98	171	10	0
	CARBON TETRACHLORIDE	UG/L	1	L 5	L 5	100	11	6	L 0
	CHLOROBENZENE	UG/L	1	L 5	L 5	100	L 5	L 5	L 5
	1,2-BICHLORDETHANE	UG/L	0	L 5	L 5		L 5	L 5	L 5
	1,1,1-TRICHLORDETHANE	UG/L	18	5	3	83	24	L 5	0
	1,1-DICHLORDETHANE	UG/L	1	L 5	L 5	100	11	L 5	L 5
	1,1,2-TRICHLORDETHANE	UG/L	5	L 5	L 5	100	L 5	L 5	L 5
	CHLOROFORM	UG/L	46	23	19	59	L 35	L 5	5
	1,1-DICHLORDETHYLENE	UG/L	4	3	4		9	L 5	5
	1,2-TRANS-DICHLORDETHYLENE	UG/L	6	L 5	1	83	23	L 5	L 0
	ETHYLBENZENE	UG/L	28	L 5	4	86	276	3	L 0
	METHYLENE CHLORIDE	UG/L	12	5	6	50	222	249	1
	METHYL CHLORIDE	UG/L	0	L 5	L 5		L 5	L 5	L 5
	BROMOFORM	UG/L	0	L 5	L 5		L 5	L 5	L 5
	DICHLOROBROMOMETHANE	UG/L	0	L 5	1		57	56	L 0

POLLUTANTS NOT LISTED WERE NEVER DETECTED
L-LESS THAN: N-D NOT DETECTED:
PRELIMINARY DATA ONLY---TO BE VERIFIED

(Continued)

TABLE 2 (Continued)

PLANT 1

FRACTION	PARAMETER	UNITS	INFLUENT	EFFLUENT PRE CL.	FINAL EFFLUENT	PCNT REM.	PRIMARY SLUDGE	WASTE ACT. SLUDGE	FLOT-ABLES
VOLATILES	TRICHLOROFLUOROMETHANE	UG/L	0	L 5	0		L 5	L 5	L 5
	CHLORODIBROMOMETHANE	UG/L	0	L 5	L 5		17	29	L 0
	TETRACHLORDETHYLENE	UG/L	51	5	5	90	293	7	0
	TOLUENE	UG/L	28	5	4	86	284	2	0
	TRICHLORDETHYLENE	UG/L	28	5	4	86	284	0	0
ACID EXTRACT	2,4,6-TRICHLOROPHENOL	UG/L	0	L 50	L 50		L 50	L 50	L 50
	PARACHLOROMETA CRESOL	UG/L	0	L 50	L 50		L 50	L 50	L 50
	2-CHLOROPHENOL	UG/L	L 50	L 50	1		L 50	L 50	L 50
	2,4-DIMETHYLPHENOL	UG/L	L 50	2	1		L 50	L 50	50
	PENTACHLOROPHENOL	UG/L	1	3	1		93	112	1
	PHENOL	UG/L	16	5	21		94	60	1
BASE-NEUTRALS	ACENAPHINENE	UG/L	0	L 10	L 10		117	L 10	L 0
	1,2,4-TRICHLOROBENZENE	UG/L	0	L 10	L 10		L 10	L 10	L 10
	HEXACHLOROBENZENE	UG/L	0	L 10	L 10		L 10	L 10	L 10
	1,2-DICHLOROBENZENE	UG/L	3	L 10	1	67	L 10	L 10	L 10
	1,3-DICHLOROBENZENE	UG/L	1	L 10	1		L 10	L 10	L 10
	1,4-DICHLOROBENZENE	UG/L	3	L 10	1	67	L 10	L 10	L 10
	3,3'-DICHLOROBENZIDINE	UG/L	L 25	L 25	1		L 25	L 25	L 25
	FLUORANTHENE	UG/L	1	L 10	2		L 10	L 10	L 10
	BIS(2-CHLORDETHYOXY) METHANE	UG/L	0	L 25	L 25		L 25	L 25	L 25
	HEXACHLOROBUTADIENE	UG/L	0	L 10	L 10		L 10	L 10	L 10
	NAPHTHALENE	UG/L	4	L 10	2	50	195	4	L 1
	BIS(2-ETHYLHEXYL) PHTHALATE	UG/L	27	15	14	40	2231	42	1
	BUTYL BENZYL PHTHALATE	UG/L	2	L 10	2		1	L 10	L 1
	DI-N-BUTYL PHIHALATE	UG/L	5	2	3	40	L 10	L 10	1
	DI-N-OCTYL PHTHALATE	UG/L	0	L 10	1		L 10	L 10	L 10
	DIETHYL PHTHALATE	UG/L	3	L 10	1	67	L 10	L 10	L 10

POLLUTANTS NOT LISTED WERE NEVER DETECTED
L-LESS THAN; N-D NOT DETECTED
PRELIMINARY DATA ONLY---TO BE VERIFIED

(Continued)

TABLE 2 (Continued)

PLANT 1

FRACTION	PARAMETER	UNITS	INFLUENT	EFFLUENT PRE CL.	FINAL EFFLUENT	PCNT REM.	PRIMARY SLUDGE	WASTE ACT. SLUDGE	FLOT-ABLES
BASE-NEUTRALS	DIMETHYL PHTHALATE	UG/L	2	L 10	1	50	L 10	L 10	L 10
	1,2-BENZANTHRACENE	UG/L	1	L 10	1		479	L 10	L 1
	BENZO (A)PYRENE	UG/L	0	L 10	L 10		L 10	L 10	L 10
	3,4-BENZOFLUORANTHENE	UG/L	L 5	L 5	L 5		675	0	L 0
	CHRYSENE	UG/L	1	L 10	1		479	L 10	L 1
	ACENAPHTHYLENE	UG/L	0	L 10	L 10		L 10	L 10	L 10
	ANTHRACENE	UG/L	4	L 10	2	50	1572	4	L 1
	1/12-BENZOPERYLENE	UG/L	0	L 25	L 25		L 25	L 25	L 25
	FLUORENE	UG/L	1	L 10	1		313	L 10	L 1
	PHENANTHRENE	UG/L	4	L 10	2	50	1572	4	L 1
	1/2:5,6-DIBENZANTHRACENE	UG/L	0	L 50	1		L 50	10	L 50
	INDEND(1,2,3-C,D) PYRENE	UG/L	0	L 50	1		L 50	8	L 50
	PYRENE	UG/L	5	L 10	3	40	754	L 10	L 1
METALS	ANTIMONY	UG/L	L 50	L 50	L 50		146	21	L 0
	ARSENIC	UG/L	L 50	L 50	L 50		1263	63	L 0
	BERYLLIUM	UG/L	L 2	L 2	L 2		37	9	L 0
	CADMIUM	UG/L	12	3	4	67	1220	344	0
	CHROMIUM	UG/L	450	42	46	90	14571	18071	0
	COPPER	UG/L	191	13	27	86	77429	8971	0
	CYANIDE	UG/L	71	NOT RUN	7	90	627	56	L 58
	LEAD	UG/L	55	L 20	L 20	100	46857	1594	L 0
	MERCURY	NG/L	278	300	300		1000	286	1
	NICKEL	UG/L	98	50	50	59	13343	3343	0
	SELENIUM	UG/L	L 50	L 50	L 50		5	21	L 0
	SILVER	UG/L	L 2	L 2	L 2	100	25	182	L 0
	THALLIUM	UG/L	L 50	L 50	L 50		2	1	L 0
	ZINC	UG/L	42	42	90	66	129714	12829	0

POLLUTANTS NOT LISTED WERE NEVER DETECTED
L-LESS THAN: N-D NOT DETECTED:
PRELIMINARY DATA ONLY---TO BE VERIFIED

(Continued)

TABLE 2 (Continued)

PLANT 1

FRACTION	PARAMETER	UNITS	INFLUENT	EFFLUENT PRE CL.	FINAL EFFLUENT	PCNT REM.	PRIMARY SLUDGE	WASTE ACT. SLUDGE	FLOT-ABLES
NON-CONV. METALS	ALUMINUM	UG/L	1458	137	203	86	NOT RUN	NOT RUN	NOT RUN
	BARIUM	UG/L	129	45	50	61	NOT RUN	NOT RUN	NOT RUN
	CALCIUM	MG/L	83	86	79	5	NOT RUN	NOT RUN	NOT RUN
	IRON	UG/L	2990	289	392	87	NOT RUN	NOT RUN	NOT RUN
	MAGNESIUM	MG/L	27	30	27		NOT RUN	NOT RUN	NOT RUN
	MANGANESE	UG/L	104	124	111		NOT RUN	NOT RUN	NOT RUN

POLLUTANTS NOT LISTED WERE NEVER DETECTED
L-LESS THAN: N-D NOT DETECTED:
PRELIMINARY DATA ONLY---TO BE VERIFIED

TABLE 3 SUMMARY OF ANALYTICAL DATA

FRACTION	PARAMETER	UNITS	PLANT 2 INFLUENT	EFFLUENT PRE CL.	FINAL EFFLUENT	PERCENT REMOVAL	COMBINED SLUDGE
CONVENTIONALS	BOD	MG/L	95	20	14	85	8457
	TOTAL SUSP. SOLIDS	MG/L	97	12	9	91	21714
	COD	MG/L	183	52	38	79	32429
	OIL & GREASE	MG/L	24	NOT RUN	8	67	3551
NON-CONVENTIONALS	TOTAL PHENOLS	UG/L	20	NOT RUN	3	85	454
	TOTAL SOLIDS	MG/L	619	496	567	8	25571
	TOTAL VOLATILE SOLIDS	MG/L	143	129	132	8	14206
	TOTAL VOL. SUS. SOLIDS	MG/L	54	7	6	89	12100
	AMMONIA NITROGEN	MG/L	12	70	71		12707
	TOC	MG/L	70	29	28	60	11929
VOLATILES	ACRYLONITRILE	UG/L	L 100	L 100	L 100		41
	BENZENE	UG/L	10	1	3	70	33
	CHLOROBENZENE	UG/L	0	0	L 5		L 5
	1,2-DICHLOROETHANE	UG/L	1	1	1		L 5
	1,1,1-TRICHLOROETHANE	UG/L	1	0	0	100	L 5
	1,1-DICHLOROETHANE	UG/L	0	L 5	L 5		L 5
	CHLOROFORM	UG/L	5	4	5		L 5
	1,1-DICHLOROETHYLENE	UG/L	2	1	2		L 5
	1,2-DICHLOROPROPANE	UG/L	0	L 5	L 5		L 5
	ETHYLBENZENE	UG/L	2	0	0	100	2
	METHYLENE CHLORIDE	UG/L	9	4	4	56	247
	DICHLOROBROMOMETHANE	UG/L	1	1	2		74
	TRICHLOROFLUOROMETHANE	UG/L	L 5	0	L 5		L 5
	CHLORODIBROMOMETHANE	UG/L	0	1	1		9
	TETRACHLOROETHYLENE	UG/L	5	3	3	40	61
	TOLUENE	UG/L	5	3	3	40	336
	TRICHLOROETHYLENE	UG/L	2	0	0	100	L 5

POLLUTANTS NOT LISTED WERE NEVER DETECTED
L-LESS THAN: N-D NOT DETECTED:
PRELIMINARY DATA ONLY---TO BE VERIFIED

(Continued)

TABLE 3 (Continued)

PLANT 2

FRACTION	PARAMETER	UNITS	INFLUENT	EFFLUENT PRE CL.	FINAL EFFLUENT	PERCENT REMOVAL	COMBINED SLUDGE
ACID EXTRACT	2-NITROPHENOL	UG/L	L 50	5	2		L 50
	4-NITROPHENOL	UG/L	L 50	33	15		L 50
	PENTACHLOROPHENOL	UG/L	1	2	1		L 50
	PHENOL	UG/L	4	4	4		4
BASE-NEUTRALS	1,2-DICHLOROBENZENE	UG/L	4	1	1	75	L 10
	1,3-DICHLOROBENZENE	UG/L	1	1	3		L 10
	1,4-DICHLOROBENZENE	UG/L	1	L 10	L 10	100	L 10
	3,3'-DICHLOROBENZIDINE	UG/L	L 25	L 25	1		L 25
	2,6-DINITROTOLUENE	UG/L	1	L 25	L 25	100	L 25
	FLUORANTHENE	UG/L	2	L 10	L 10	100	L 10
	ISOPHORONE	UG/L	1	L 25	L 25	100	L 25
	NAPHTHALENE	UG/L	4	1	1	75	91
	BIS(2-ETHYLHEXYL)PHTHALATE	UG/L	10	5	4	60	1486
	BUTYL BENZYL PHTHALATE	UG/L	5	3	4	20	1
	DI-N-BUTYL PHTHALATE	UG/L	4	3	3	25	L 10
	DI-N-OCTYL PHTHALATE	UG/L	3	1	1	67	L 10
	DIETHYL PHTHALATE	UG/L	4	1	1	75	L 10
	DIMETHYL PHYTHALATE	UG/L	2	1	1	50	L 10
	1,2-BENZANTHRACENE	UG/L	L 10	1	1		0
	BENZO (A)PYRENE	UG/L	1	L 10	L 10	100	L 10
	3,4-BENZOFLUORANTHENE	UG/L	1	L 5	L 5	100	43
	11,12-BENZOFLUORANTHENE	UG/L	1	L 5	L 5	100	L 5
	CHRYSENE	UG/L	L 10	1	1		8
	ACENAPHTHYLENE	UG/L	L 10	1	1		L 10
	ANTHRACENE	UG/L	1	L 10	L 10	100	91
	PHENANTHRENE	UG/L	1	L 10	L 10	100	91
	PYRENE	UG/L	2	L 10	L 10	100	45

POLLUTANTS NOT LISTED WERE NEVER DETECTED
L-LESS THAN: N-D NOT DETECTED:
PRELIMINARY DATA ONLY---TO BE VERIFIED

(Continued)

TABLE 3 (Continued)

PLANT 2

FRACTION	PARAMETER	UNITS	INFLUENT	EFFLUENT PRE CL.	FINAL EFFLUENT	PERCENT REMOVAL	COMBINED SLUDGE
METALS	ANTIMONY	UG/L	L 50	L 50	L 50		39
	ARSENIC	UG/L	L 50	L 50	L 50		149
	BERYLLIUM	UG/L	L 2	L 2	L 2		12
	CADMIUM	UG/L	4	L 2	L 2	100	305
	CHROMIUM	UG/L	71	26	22	69	8114
	COPPER	UG/L	54	11	10	81	10700
	CYANIDE	UG/L	77	NOT RUN	142		1819
	LEAD	UG/L	16	6	3	81	7386
	MERCURY	NG/L	214	33	57	73	3286
	NICKEL	UG/L	30	22	20	33	3097
	SELENIUM	UG/L	L 50	L 50	L 50		27
	SILVER	UG/L	1	5	0	100	78
	THALLIUM	UG/L	L 50	L 50	L 50		1
	ZINC	UG/L	278	83	52	81	26743
NON-CONV. METALS	ALUMINUM	UG/L	537	74	51	91	NOT RUN
	BARIUM	UG/L	74	26	25	66	NOT RUN
	CALCIUM	MG/L	58	64	65		NOT RUN
	IRON	UG/L	1640	198	188	89	NOT RUN
	MAGNESIUM	MG/L	12	14	12		NOT RUN
	MANGANESE	UG/L	280	194	175	30	NOT RUN
	MOLYBDENUM	UG/L	NOT RUN	NOT RUN	6		NOT RUN
	SODIUM	MG/L	NOT RUN	NOT RUN	6		NOT RUN
	TIN	UG/L	NOT RUN	NOT RUN	6		NOT RUN
	TITANIUM	UG/L	NOT RUN	NOT RUN	6		NOT RUN
	VANADIUM	UG/L	NOT RUN	NOT RUN	6		NOT RUN
	YTTRIUM	UG/L	NOT RUN	NOT RUN	6		NOT RUN

POLLUTANTS NOT LISTED WERE NEVER DETECTED
L-LESS THAN: N-D NOT DETECTED:
PRELIMINARY DATA ONLY---TO BE VERIFIED

TABLE 4 SUMMARY OF ANALYTICAL DATA

PLANT 3

FRACTION	PARAMETER	UNITS	INFLUENT	EFFLUENT PRE CL.	FINAL EFFLUENT	PCNT REM.	PRIMARY SLUDGE	COMB. SLUDGE	GRAVITY THICK. OVERFLOW
CONVENTIONALS	BOD	MG/L	134	12	14	90	5538	4426	55
	TOTAL SUSP. SOLIDS	MG/L	265	12	44	83	40039	31859	126
	COD	MG/L	417	49	45	89	44050	22577	422
	OIL & GREASE	MG/L	44	6	4	91	8304	1799	38
NON CONVENTIONALS	TOTAL PHENOLS	MG/L	116	11	15	87	3377	1615	39
	TOTAL SOLIDS	MG/L	555	322	351	37	41947	30020	480
	TOTAL DISS. SOLIDS	MG/L	279	293	299		1021	6076	342
	SETTLEABLE SOLIDS	ML/L	8	L 1	L 1	100	NOT RUN	NOT RUN	3
	TOTAL VOLATILE SOLIDS	MG/L	235	76	77	67	29725	20507	101
	VOLATILE DISS. SOLIDS	MG/L	67	69	58	13	573	2619	64
	TOTAL VOL. SUS. SOLIDS	MG/L	151	4	15	90	29065	17882	106
	AMMONIA NITROGEN	UG/L	16	1	1	94	120	31	23
	TOC	MG/L	216	24	34	84	21771	15194	230
VOLATILES	BENZENE	UG/L	2	L 5	L 5	100	34	2	L 5
	1,1,1-TRICHLOROETHANE	UG/L	59	2	2	97	17	N-D	60
	1,1-DICHLOROETHANE	UG/L	0	L 5	L 5		N-D	N-D	L 5
	2-CHLOROETHYL VINYL ETHER	UG/L	1	L 5	L 5	100	N-D	N-D	L 5
	CHLOROFORM	UG/L	39	7	28	28	N-D	N-D	50
	1,1-DICHLOROETHYLENE	UG/L	2	L 5	L 5	100	2373	N-D	3
	1,2-DICHLOROPROPANE	UG/L	0	L 5	L 5		10	N-D	L 5
	ETHYLBENZENE	UG/L	36	L 5	L 5	100	203	93	60
	METHYLENE CHLORINE	UG/L	10	3	3	70	8	1	3
	METHYL CHLORIDE	UG/L	L 5	L 5	L 5		33	N-D	L 5
	DICHLOROBROMOMETHANE	UG/L	0	L 5	5		N-D	N-D	L 5
	TRICHLOROFLUOROMETHANE	UG/L	0	L 5	L 5		N-D	N-D	L 5

POLLUTANTS NOT LISTED WERE NEVER DETECTED
L-LESS THAN: N-D NOT DETECTED:
PRELIMINARY DATA ONLY---TO BE VERIFIED

(Continued)

TYPING GUIDE SHEET
EPA-287 (Cin.)
(4-76)

TABLE 4 (Contined)

PLANT 3

FRACTION	PARAMETER	UNITS	INFLUENT	EFFLUENT PRE CL.	FINAL EFFLUENT	PCNT REM.	PRIMARY SLUDGE	COMB. SLUDGE	GRAVITY THICK OVERFLOW
VOLATILES	CHLORODIBROMOMETHANE	UG/L	L 5	L 5	1		N-D	N-D	L 5
	TETRACHLOROETHYLENE	UG/L	45	6	3	93	N-D	1601	50
	TOLUENE	UG/L	13	1	1	92	260	54	20
	TRICHLOROETHYLENE	UG/L	2	1	L 5	100	38	N-D	3
	VINYL CHLORIDE	UG/L	L 5	L 5	L 5		301	N-D	L 5
ACID EXTRACT	PENTACHLOROPHENOL	UG/L	L 50	L 50	L 50		N-D	30	L 50
	PHENOL	UG/L	25	L 50	L 50	100	277	4297	10
BASE-NEUTRALS	1,2,4-TRICHLOROBENZENE	UG/L	L 10	L 10	L 10		41	N-D	L 10
	1,2-DICHLOROBENZENE	UG/L	0	L 10	L 10		N-D	N-D	L 10
	1,3-DICHLOROBENZENE	UG/L	0	L 10	L 10		N-D	N-D	L 10
	1,4-DICHLOROBENZENE	UG/L	0	L 10	L 10		25	N-D	L 10
	FLUORANTHENE	UG/L	0	L 10	L 10		67	23	L 10
	NAPHTHALENE	UG/L	3	L 10	L 10	100	78	N-D	5
	BIS(2-ETHYLHEXL) PHTHALATE	UG/L	29	9	5	83	300	157	30
	BUTYL BENZYL PHTHALATE	UG/L	6	L 10	L 10	100	57	N-D	L 10
	DI-N-BUTYL PHTHALATE	UG/L	7	3	5	29	263	37	5
	DI-N-OCTYL PHTHALATE	UG/L	4	L 10	L 10	100	N-D	N-D	L 10
	DIETHYL PHTHALATE	UG/L	5	1	1	80	N-D	N-D	L 10
	DIMETHYL PHTHALATE	UG/L	2	L 10	L 10	100	N-D	N-D	L 10
	1,2-BENZANTHRACENE	UG/L	0	L 10	L 10		15	N-D	L 10
	BENZO (A)PYRENE	UG/L	0	L 10	L 10		N-D	N-D	L 10
	3,4-BENZOFLUORANTHENE	UG/L	0	L 5	L 5		N-D	N-D	L 5
	11,12-BENZOFLUORANTHENE	UG/L	0	L 5	L 5		N-D	N-D	L 5
	CHRYSENE	UG/L	0	L 10	L 10		15	N-D	L 10
	ANTHRACENE	UG/L	2	L 10	L 10	100	260	104	L 10
	FLUORENE	UG/L	L 10	L 10	L 10		10	N-D	L 10
	PHENANTHRENE	UG/L	2	L 10	L 10	100	260	104	L 10
	PYRENE	UG/L	0	L 10	L 10		66	32	L 10

POLLUTANTS NOT LISTED WERE NEVER DETECTED
L-LESS THAN: N-D NOT DETECTED:
PRELIMINARY DATA ONLY---TO BE VERIFIED

(Continued)

TABLE 4 (Continued)

PLANT 3

FRACTION	PARAMETER	UNITS	INFLUENT	EFFLUENT PRE CL.	FINAL EFFLUENT	PCNT REM.	PRIMARY SLUDGE	COMB. SLUDGE	GRAVITY THICK OVERFLOW
METALS	ANTIMONY	UG/L	L 4	L 4	L 4		130	52	L 4
	ARSENIC	UG/L	3	2.	L 5	100	403	130	5
	BERYLLIUM	UG/L	L 1	L 5	0		13	10	L 1
	CADMIUM	UG/L	4	1	6		229	42	L 1
	CHROMIUM	UG/L	29	7	10	66	4433	4750	17
	COPPER	UG/L	285	39	43	85	25667	20500	195
	CYANIDE	UG/L	96	53	36	63	20530	7223	60
	LEAD	UG/L	97	30	44	55	6833	1475	45
	NICKEL	UG/L	62	42	80		547	478	44
	SELENIUM	UG/L	L 4	L 4	L 4		28	12	L 4
	SILVER	UG/L	1	L 4	L 4	100	417	338	L 4
	ZINC	UG/L	317	70	61	81	27667	16000	194
NON-CONV. METALS	ALUMINUM	UG/L	2384	79	251	89	NOT RUN	NOT RUN	711
	BARIUM	UG/L	116	L 1	1	99	NOT RUN	NOT RUN	35
	BORON	UG/L	289	252	258	11	NOT RUN	NOT RUN	109
	CALCIUM	MG/L	24	27	19	21	NOT RUN	NOT RUN	42
	COBOLT	UG/L	26	6	11	58	NOT RUN	NOT RUN	11
	IRON	UG/L	12028	116	209	98	NOT RUN	NOT RUN	3402
	MAGNESIUM	MG/L	4	3	3	25	NOT RUN	NOT RUN	4
	MANGANESE	UG/L	343	17	23	93	NOT RUN	NOT RUN	303
	MOLYBDENUM	UG/L	147	152	151		NOT RUN	NOT RUN	212
	SODIUM	MG/L	58	67	66		NOT RUN	NOT RUN	64
	TIN	UG/L	40	3	4	90	NOT RUN	NOT RUN	14
	TITANIUM	UG/L	159	3	6	96	NOT RUN	NOT RUN	59
	VANADIUM	UG/L	71	28	29	59	NOT RUN	NOT RUN	44
	YITRIUM	UG/L	4	4	6		NOT RUN	NOT RUN	2

POLLUTANTS NOT LISTED WERE NEVER DETECTED
L-LESS THAN: N-D NOT DETECTED:
PRELIMINARY DATA ONLY---TO BE VERIFIED

TABLE 5 SUMMARY OF ANALYTICAL DATA

PLANT 4

FRACTION	PARAMETER	UNITS	INFLUENT	FINAL EFFLUENT	PERCENT REMOVAL	COMBINED SLUDGE	DIGESTED SLUDGE
CONVENTIONALS	BOD	MG/L	152	22	86	18300	5500
	TOTAL SUSP. SOLIDS	MG/L	164	43	74	59667	41917
	COD	MG/L	343	81	73	59783	34003
	OIL & GREASE	MG/L	117	16	86	10120	9040
NON-CONVENTIONALS	TOTAL PHENOLS	MG/L	123	28	77	677	1158
	TOTAL SOLIDS	MG/L	402	276	31	63583	45917
	TOTAL DISS. SOLIDS	MG/L	252	207	10	1290	859
	SETTLEABLE SOLIDS	ML/L	5	L 1	100	6350	4530
	TOTAL VOLATILE SOLIDS	MG/L	170	112	37	34683	21533
	VOLATILE DISS. SOLIDS	MG/L	80	58	27	1050	405
	TOTAL VOL. SUS. SOLIDS	MG/L	117	29	75	29933	15057
	AMMONIA NITROGEN	UG/L	9	8	11	207	523
	TOC	MG/L	99	38	62	35830	11503
VOLATILES	BENZENE	UG/L	L 1	L 1		40	20
	CARBON TETRACHLORIDE	UG/L	L 2	L 2		270	N-D
	CHLOROBENZENE	UG/L	L 1	L 1		N-D	252
	1,2-DICHLOROETHANE	UG/L	L 2	L 2		N-D	55
	1,1,1-TRICHLOROETHANE	UG/L	284	09	69	507	37
	1,1,2-TRICHLOROETHANE	UG/L	L 2	L 2		441	N-D
	1,1,2,2-TETRACHLOROETHANE	UG/L	10	2	89	43	194
	CHLOROETHANE	UG/L	L 15	L 15		N-D	1
	DIS(CHLORIMETHYL) ETHER	UG/L	NOT RUN	NOT RUN		N-D	1
	2-CHLOROETHYL VINYL ETHER	UG/L	L 8	L 8		N-D	1
	CHLOROFORM	UG/L	8	3	63	1	1
	1,1-DICHLOROETHYLENE	UG/L	13	3	77	2347	3
	1,2-TRANS-DICHLOROETHYLENE	UG/L	25	7	72	54993	9800
	1,2-DICHLOROPROPANE	UG/L	L 1	L 1		4	7
	ETHYLBENZENE	UG/L	44	L 1	100	1467	910

POLLUTANTS NOT LISTED WERE NEVER DETECTED
L=LESS THAN: N-D NOT DETECTED
PRELIMINARY DATA ONLY --TO BE VERIFIED

(Continued)

TABLE 5 SUMMARY OF ANALYTICAL DATA

PLANT 4

FRACTION	PARAMETER	UNITS	INFLUENT	FINAL EFFLUENT	PERCENT REMOVAL	COMBINED SLUDGE	DIGESTED SLUDGE
VOLATILES	METHYLENE	UG/L	282	128	55	142	16
	DICHLOROBROMOMETHANE	UG/L	L 1	L 1		04	N-D
	TETRACHLOROETHYLENE	UG/L	385	134	65	950	10
	TOLUENE	UG/L	36	2	94	984	1847
	TRICHLOROETHYLENE	UG/L	497	37	93	467	120
	VINYL CHLORIDE	UG/L	L 33	L 33		N-D	27
ACID EXTRACT	2/4-DIMETHYLPHENOL	UG/L	2	L 1	100	N-D	N-D
	2-NITROPHENOL	UG/L	L 2	L 2		N-D	37
	2,4-DINITROPHENOL	UG/L	L 50	L 50		N-D	200
	PENTACHLOROPHENOL	UG/L	6	L 5	100	25	N-D
	PHENOL	UG/L	14	1	93	103	70
BASE NEUTRALS	ACENAPTHLENE	UG/L	L 4	L 4		N-D	65
	1,2-DICHLOROBENZENE	UG/L	105	6	94	262	116
	1,3-DICHLOROBENZENE	UG/L	L 5	L 5		252	10
	1,4-DICHLOROBENZENE	UG/L	13	3	77	1128	125
	FLUORANTHENE	UG/L	L 3	L 3		114	51
	ISOPHORONE	UG/L	L 10	2		N-D	N-D
	NAPTHALENE	UG/L	51	L 3	100	640	445
	N-NITROSODINE THYLAMIDE	UG/L	L 49	3		N-D	N-D
	DIS(2-ETHYLHEXYL) PHTHALATE	UG/L	31	11	65	8108	8437
	BUTYL BENZYL PHTHALATE	UG/L	60	2	97	2650	4400
	DI-N-BUTYL PHTHALATE	UG/L	18	6	67	427	33
	DIETHYL PHTHALATE	UG/L	7	0	100	N-D	N-D
	1,2-BENZANTHRACENE	UG/L	L 3	L 3		15	6
	3,4-BENZOFLUORANTHENE	UG/L	L 8	L 8		23	25
	CHRYSENE	UG/L	L 3	L 3		13	6
	ACENAPHTHYLENE	UG/L	L 2	L 2		N-D	28
	ANTHRACENE	UG/L	0	L 3		602	375
	FLUORENE	UG/L	L 3	L 3		19	38
	PHENAMTHRENE	UG/L	0	L 3		602	375
	INDENO(1,2,3-C,D) PYRENE	UG/L	1	L 15	100	N-D	N-D
	PYRENE	UG/L	L 15	L 15		121	90

POLLUTANTS NOT LISTED WERE NEVER DETECTED
L-LESS THAN N-D NOT DETECTED:
PRELIMINARY DATA ONLY--TO BE VERIFIED

(Continued)

TABLE 5 SUMMARY OF ANALYTICAL DATA

PLANT 4

FRACTION	PARAMETER	UNITS	INFLUENT	FINAL EFFLUENT	PERCENT REMOVAL	COMBINED SLUDGE	DIGESTED SLUDGE
PESTICIDES	DIELDRIN	NG/L	5	L 30	100	L 1000	L 1000
	HEPTACHLOR	NG/L	13	L 20	100	L 1000	L 1000
	ALPHA-DMC	NG/L	L 30	5		L 1000	L 1000
	GAMMA-DMC	NG/L	55	163		L 1000	L 1000
METALS	ANTIMONY	UG/L	L 50	L 50		116	116
	ARSENIC	UG/L	L 50	L 50		403	333
	BERYLLIUM	UG/L	L 2	L 2		25	30
	CADMIUM	UG/L	80	29	64	17667	26167
	COPPER	UG/L	47	17	64	10000	15333
	CYANIDE	UG/L	37	12	68	193	407
	LEAD	UG/L	127	53	50	41000	49333
	MERCURY	NG/L	1250	450	64	NOT RUN	NOT RUN
	NICKEL	UG/L	20	7	65	2567	3083
	SELENIUM	UG/L	[illegible]	L 50		20	23
	SILVER	UG/L	[illegible]	3	83	1966	2378
	ZINC	UG/L	94	223	55	14333	171667
NON-CONV. METALS	ALUMINUM	UG/L	2460	584	76	NOT RUN	NOT RUN
	BARIUM	UG/L	151	38	75	NOT RUN	NOT RUN
	CALCIUM	MG/L	16	36		NOT RUN	NOT RUN
	IRON	UG/L	7358	2365	68	NOT RUN	NOT RUN
	MAGNESIUM	MG/L	3	2	33	NOT RUN	NOT RUN
	MANGANESE	UG/L	234	179	24	NOT RUN	NOT RUN
	SODIUM	MG/L	32	29	9	NOT RUN	NOT RUN

POLLUTANTS NOT LISTED WERE NEVER DETECTED
L-LESS THAN: N-D NOT DETECTED:
PRELIMINARY DATA ONLY--TO BE VERIFIED

TABLE 6 SUMMARY OF ANALYTICAL DATA

PLANT 5

FRACTION	PARAMETER	UNITS	INFLUENT	FINAL EFFLUENT	PERCENT REMOVAL	PRIMARY SLUDGE	DIGESTED SLUDGE
CONVENTIONALS	BOD	MG/L	130	13	91	15671	3102
	TOTAL SUSP. SOLIDS	MG/L	147	12	92	26433	17430
	COD	MG/L	374	60	82	35203	12712
	OIL & GREASE	MG/L	33	3	91	4100	2746
NON-CONVENTIONALS	TOTAL PHENOLS	MG/L	30	8	73	99	258
	TOTAL SOLIDS	MG/L	889	695	22	29064	18407
	TOTAL DISS. SOLIDS	MG/L	742	683	8	3431	1016
	SETTLEABLE SOLIDS	MG/L	7	L 1	100	992	860
	TOTAL VOLATILE SOLIDS	MG/L	400	371	23	21597	8712
	VOLATILE DISS. SOLIDS	MG/L	360	360		2426	359
	TOTAL VOL. SUS. SOLIDS	MG/L	120	11	91	19182	8362
	AMMONIA NITROGEN	UG/L	12	7	42	35	419
	TOC	MG/L	64	14	78	7527	1275
VOLATILES	BENZENE	UG/L	5	1	80	42	5
	CHLOROBENZENE	UG/L	0	1		N-D	1
	1,1,1-TRICHLOROETHANE	UG/L	19	3	84	N-D	2
	1,1,2,2-TETRACHLOROETHANE	UG/L	1	L 1	100	40	45
	2-CHLOROETHYL VINYL ETHER	UG/L	L 8	L 8		N-D	0
	CHLOROFORM	UG/L	12	7	42	2	6
	1,1-DICHLOROETHYLENE	UG/L	L 1	L 1		22	N-D
	1,2-TRANS-DICHLOROETHYLENE	UG/L	2	L 2	100	1541	22
	1,2-DICHLOROPROPANE	UG/L	L 1	L 1		0	N-D
	1,3-DICHLOROPROPYLENE	UG/L	4	L 2	100	N-D	N-D
	ETHYLBENZENE	UG/L	10	1	90	166	73
	METHYLENE CHLORIDE	UG/L	676	468	31	101	11
	METHYL CHLORIDE	UG/L	L 34	L 34		45	9
	DICHLOROBROMOMETHANE	UG/L	3	2	33	N-D	N-D
	DICHLORODIFLUOROMETHANE	UG/L	L 30	5		N-D	N-D

POLLUTANTS NOT LISTED WERE NEVER DETECTED
L-LESS THAN; N-D NOT DETECTED;
PRELIMINARY DATA ONLY -- TO BE VERIFIED

(Continued)

TABLE 6 (Continued)

PLANT 5

FRACTION	PARAMETER	UNITS	INFLUENT	FINAL EFFLUENT	PERCENT REMOVAL	PRIMARY SLUDGE	DIGESTED SLUDGE
VOLATILES	CHLORODIBROMOMETHANE	UG/L	1	1		3	1
	TETRACHLOROETHYLENE	UG/L	115	26	77	14	N-D
	TOLUENE	UG/L	37	0	100	199	124
	TRICHLOROETHYLENE	UG/L	49	14	71	163	2
	VINYL CHLORIDE	UG/L	L 33	L 33		1792	117
ACID EXTRACT	2,4,6-TRICHLOROPHENOL	UG/L	0	L 2		N-D	N-D
	2,4-DICHLOROPHENOL	UG/L	L 1	L 2		N-D	4
	2,4-DIMETHYLPHENOL	UG/L	0	L 1		N-D	N-D
	PENTACHLOROPHENOL	UG/L	L 5	L 5		N-D	5
	PHENOL	UG/L	1	0	100	27	40
BASE NEUTRALS	ACENAPHTHENE	UG/L	L 4	L 4		20	13
	1,2-DICHLOROBENZENE	UG/L	L 5	L 5		3	N-D
	1,4-DICHLOROBENZENE	UG/L	L 5	L 5		15	6
	FLUORANTHENE	UG/L	L 3	L 3		N-D	10
	NAPHTHALENE	UG/L	3	L 3	100	118	32
	DIS(2-ETHYLHEXYL) PHTHALATE	UG/L	20	6	79	3598	4170
	BUTYL BENZYL PHTHALATE	UG/L	6	L 2	100	450	152
	DI-N-BUTYL PHTHALATE	UG/L	3	L 2	100	N-D	N-D
	DI-N-OCTYL PHTHALATE	UG/L	L 4	L 4		47	48
	DIETHYL PHTHALATE	UG/L	2	L 2	100	N-D	N-D
	ANTHRACENE	UG/L	L 3	L 3		92	102
	PHENANTHRENE	UG/L	L 3	L 3		92	102
	PYRENE	UG/L	L 2	L 2		10	9
PESTICIDES	BETA-BHC	NG/L	L 1000	12		L 1000	L 1000
	GAMMA-BHC	NG/L	L 1000	22		L 1000	L 1000

POLLUTANTS NOT LISTED WERE NEVER DETECTED
L-LESS THAN; N-D NOT DETECTED;
PRELIMINARY DATA ONLY -- TO BE VERIFIED

(Continued)

TABLE 6 (Continued)

PLANT 5

FRACTION	PARAMETER	UNITS	INFLUENT	FINAL EFFLUENT	PERCENT REMOVAL	PRIMARY SLUDGE	DIGESTED SLUDGE
METALS	ANTIMONY	UG/L	L 50	L 50		91	50
	ARSENIC	UG/L	L 50	L 50		78	69
	BERYLLIUM	UG/L	1	L 2	100	6	6
	CADMIUM	UG/L	6	1	83	390	310
	CHROMIUM	UG/L	102	35	66	8317	7767
	COPPER	UG/L	70	31	56	3000	2767
	CYANIDE	UG/L	12	5	58	221	28
	LEAD	UG/L	67	4	94	8967	9167
	NICKEL	UG/L	12	L 10	100	1077	1240
	SELENIUM	UG/L	L 50	L 50		53	41
	SILVER	UG/L	23	2	91	1103	800
	ZINC	UG/L	248	66	73	23833	24167
NON-CONV. METALS	ALUMINUM	UG/L	817	155	81	NOT RUN	NOT RUN
	BARIUM	UG/L	101	54	47	NOT RUN	NOT RUN
	CALCIUM	MG/L	74	70	5	NOT RUN	NOT RUN
	IRON	UG/L	1192	274	77	NOT RUN	NOT RUN
	MAGNESIUM	MG/L	28	27	4	NOT RUN	NOT RUN
	MANGANESE	UG/L	234	204	13	NOT RUN	NOT RUN
	SODIUM	MG/L	89	87	2	NOT RUN	NOT RUN

POLLUTANTS NOT LISTED WERE NEVER DETECTED
L-LESS THAN; N-D NOT DETECTED;
PRELIMINARY DATA ONLY -- TO BE VERIFIED

TABLE 7 SUMMARY OF ANALYTICAL DATA

PLANT 6

FRACTION	PARAMETER	UNITS	INFLUENT	FINAL EFFLUENT	PERCENT REMOVAL	PRIMARY SLUDGE	DIGESTED SLUDGE
CONVENTIONALS	BOD	MG/L	263	18	93	18857	16856
	TOTAL SUSP. SOLIDS	MG/L	632	27	96	51342	47758
	COD	MG/L	904	131	86	55386	51787
	OIL & GREASE	MG/L	54	2	96	4988	4948
NON-CONVENTIONALS	TOTAL PHENOLS	UG/L	309	38	88	4672	7420
	TOTAL SOLIDS	MG/L	1370	683	50	53717	49232
	TOTAL DISS. SOLIDS	MG/L	678	646	5	4618	1140
	SETTLEABLE SOLIDS	ML/L	493	17	97	1825	1775
	TOTAL VOLATILE SOLIDS	MG/L	678	132	81	41398	37662
	VOLATILE DISS. SOLIDS	MG/L	161	117	27	382	445
	TOTAL VOL. SUS. SOLIDS	MG/L	530	18	97	41017	37250
	AMMONIA NITROGEN	MG/L	20	12	40	82	585
	TOC	MG/L	391	40	90	24008	25625
VOLATILES	BENZENE	UG/L	1	0	100	12	11
	CARBON TETRACHLORIDE	UG/L	L 2	L 2		10	N-D
	CHLOROBENZENE	UG/L	L 1	L 1		0	0
	1,2-DICHLOROETHANE	UG/L	11	1	91	N-D	N-D
	1,1,1-TRICHLOROETHANE	UG/L	417	47	89	33	N-D
	1,1-DICHLOROETHANE	UG/L	8	1	88	212	N-D
	1,1,2-TRICHLOROETHANE	UG/L	1	L 2	100	N-D	N-D
	1,1,2,2-TETRACHLOROETHANE	UG/L	L 1	L 1		N-D	1
	CHLOROETHANE	UG/L	L 15	L 15		167	1800
	CHLOROFORM	UG/L	6	3	50	N-D	N-D
	1,1-DICHLOROETHYLENE	UG/L	43	L 1	100	N-D	N-D
	1,2-TRANS-DICHLOROETHYLENE	UG/L	35	8	77	878	90
	ETHYLBENZENE	UG/L	1	L 1	100	317	392
	METHYLENE CHLORIDE	UG/L	32	18	44	64	28

POLLUTANTS NOT LISTED WERE NEVER DETECTED
L-LESS THAN; N-D NOT DETECTED;
PRELIMINARY DATA ONLY -- TO BE VERIFIED

(Continued)

TABLE 7 (Continued)

PLANT 6

FRACTION	PARAMETER	UNITS	INFLUENT	FINAL EFFLUENT	PERCENT REMOVAL	PRIMARY SLUDGE	DIGESTED SLUDGE
VOLATILES	METHYL CHLORIDE	UG/L	33	L 34	100	N-D	N-D
	DICHLOROBROMOMETHANE	UG/L	1	0	100	N-D	N-D
	TRICHLOROFLUOROMETHANE	UG/L	6	6		N-D	N-D
	TETRACHLOROETHYLENE	UG/L	9	0	100	58	52
	TOLUENE	UG/L	191	20	90	1642	423
	TRICHLOROETHYLENE	UG/L	487	64	87	30	4
	VINYL CHLORIDE	UG/L	1698	101	94	33167	33800
ACID EXTRACT	PARACHLOROMETA CRESOL	UG/L	9	1	89	N-D	N-D
	2,4-DICHLOROPHENOL	UG/L	1	L 1	100	N-D	N-D
	PENTACHLOROPHENOL	UG/L	15	1	93	N-D	N-D
	PHENOL	UG/L	1	0	100	882	2000
BASE-NEUTRALS	ACENAPHTHENE	UG/L	1	1		N-D	N-D
	1,3-DICHLOROBENZENE	UG/L	3	L 1	100	N-D	N-D
	1,4-DICHLOROBENZENE	UG/L	1	L 1	100	N-D	N-D
	2,4-DINITROTOLUENE	UG/L	1	1		N-D	N-D
	NAPHTHALENE	UG/L	1	L 2	100	N-D	N-D
	BIS(2-ETHYLHEXYL) PHTHALATE	UG/L	64	9	86	5200	4086
	BUTYL BENZYL PHTHALATE	UG/L	L 5	0		1500	N-D
	DI-N-BUTYL PHTHALATE	UG/L	38	11	71	483	N-D
	DIETHYL PHTHALATE	UG/L	15	2	87	N-D	N-D
	1,2-BENZANTHRACENE	UG/L	L 5	1		565	124
	CHRYSENE	UG/L	L 5	1		565	124
	ANTHRACENE	UG/L	52	11	79	1505	994
	1,12-BENZOPERYLENE	UG/L	6	1	83	N-D	N-D
	FLUORENE	UG/L	L 5	0		N-D	N-D
	PHENANTHRENE	UG/L	52	11	79	1505	994

POLLUTANTS NOT LISTED WERE NEVER DETECTED
L-LESS THAN; N-D NOT DETECTED;
PRELIMINARY DATA ONLY -- TO BE VERIFIED

(Continued)

TABLE 7 (Continued)

PLANT 6

FRACTION	PARAMETER	UNITS	INFLUENT	FINAL EFFLUENT	PERCENT REMOVAL	PRIMARY SLUDGE	DIGESTED SLUDGE
METALS	ANTIMONY	UG/L	L 50	L 50		393	350
	ARSENIC	UG/L	L 50	L 50		310	212
	BERYLLIUM	UG/L	L 2	L 2		11	9
	CADMIUM	UG/L	1076	65	94	82500	79833
	CHROMIUM	UG/L	1390	62	96	74333	73833
	COPPER	UG/L	760	47	94	51333	46000
	CYANIDE	UG/L	99	389		22123	17597
	LEAD	UG/L	199	18	91	14767	7617
	MERCURY	NG/L	3233	200	94	602	487
	NICKEL	UG/L	701	294	50	17000	17500
	SELENIUM	UG/L	L 50	L 50		162	152
	SILVER	UG/L	15	3	80	823	802
	ZINC	UG/L	4935	475	90	386667	365000
NON-CONV. METALS	ALUMINUM	UG/L	2380	134	94	NOT RUN	NOT RUN
	BARIUM	UG/L	302	31	90	NOT RUN	NOT RUN
	CALCIUM	MG/L	56	46	18	NOT RUN	NOT RUN
	IRON	UG/L	7363	421	94	NOT RUN	NOT RUN
	MAGNESIUM	MG/L	15	13	13	NOT RUN	NOT RUN
	MANGANESE	UG/L	285	151	47	NOT RUN	NOT RUN
	SODIUM	MG/L	141	135	4	NOT RUN	NOT RUN

POLLUTANTS NOT LISTED WERE NEVER DETECTED
L-LESS THAN: N-D NOT DETECTED:
PRELIMINARY DATA ONLY---TO BE VERIFIED

TABLE 8 SUMMARY OF ANALYTICAL DATA

PLANT 7

FRACTION	PARAMETER	UNITS	INFLUENT	EFFLUENT PRE CL.	PCNT REM.	COMBINED SLUDGE	HEAT TREATED SLUDGE	HEAT TREATMENT DECANT
CONVENTIONALS	BOD	MG/L	169	69	83	27404	29013	13964
	TOTAL SUSP. SOLIDS	MG/L	135	18	87	35057	26313	2077
	COD	MG/L	328	97	70	52081	57922	20110
	OIL & GREASE	MG/L	41	9	78	7983	9608	533
NON-CONVENTIONALS	TOTAL PHENOLS	UG/L	55	8	85	1133	3512	4122
	TOTAL SOLIDS	MG/L	862	849	2	41248	34023	14116
	TOTAL DISS. SOLIDS	MG/L	718	831		4262	9578	11239
	SETTLEABLE SOLIDS	ML/L	3	L 1	100	670	343	33
	TOTAL VOLATILE SOLIDS	MG/L	329	204	14	27934	23131	11496
	VOLATILE DISS. SOLIDS	MG/L	225	271		2243	7581	9881
	TOTAL VOL. SUS. SOLIDS	MG/L	105	14	87	22103	15217	1615
	AMMONIA NITROGEN	MG/L	13	14		257	516	433
	TOC	MG/L	65	24	63	9050	8433	8767
VOLATILES	BENZENE	UG/L	1	L 5	100	95	507	22
	CHLOROBENZENE	UG/L	L 5	L 5		6	1	0
	1,1,1-TRICHLOROETHANE	UG/L	47	7	85	N-D	N-D	L 5
	1,1-DICHLOROETHANE	UG/L	1	L 5	100	352	N-D	L 5
	1,1,2,2-TETRACHLOROETHANE	UG/L	L 5	L 5		26	L N-D	L 5
	CHLOROFORM	UG/L	5	1	80	7	N-D	L 5
	1,2-TRANS_DICHLOROETHYLENE	UG/L	2	3		1517	283	9
	1,2-DICHLOROPROPANE	UG/L	L 5	L 5		L N-D	8	L 5
	1,3-DICHLOROPROPYLENE	UG/L	L 5	L 5		N-D	55	L 5
	ETHYLBENZENE	UG/L	22	L 5	100	2100	460	18
	METHYLENE CHLORIDE	UG/L	36	23	36	8	1	38
	DICHLORODIFLUOROMETHANE	UG/L	L 5	L 5		32	N-D	L 5
	TETRACHLOROETHYLENE	UG/L	15	3	80	1	15	L 5

POLLUTANTS NOT LISTED WERE NEVER DETECTED
L-LESS THAN: N-D NOT DETECTED:
PRELIMINARY DATA ONLY---TO BE VERIFIED

(Continued)

TABLE 8 (Continued)

PLANT 7

FRACTION	PARAMETER	UNITS	INFLUENT	EFFLUENT PRE CL.	PCNT REM.	COMBINED SLUDGE	HEAT TREATED SLUDGE	HEAT TREATMENT DECANT
ACID EXTRACT	PENTACHLOROPHENOL	UG/L	L 27	L 250		1000	N-D	L 250
	PHENOL	UG/L	9	L 300	100	173	1717	907
BASE-NEUTRALS	1,2-DICHLOROBENZENE	UG/L	3	L 11	100	233	50	17
	1,3-DICHLOROBENZENE	UG/L	L 11	L 11		35	N-D	L 100
	1,4-DICHLOROBENZENE	UG/L	L 11	L 11		28	10	L 100
	FLUORANTHENE	UG/L	L 5	L 11		143	13	L 50
	NAPHTHALENE	UG/L	8	L 11	100	147	16	2
	BIS(2-ETHYLHEXYL) PHTHALATE	UG/L	197	90	54	11257	10117	1498
	BUTYL BENZYL PHTHALATE	UG/L	7	L 11	100	1162	735	L 100
	DI-N-BUTYL PHTHALATE	UG/L	3	L 11	100	318	265	L 100
	DIETHYL PHTHALATE	UG/L	7	L 11	100	N-D	N-D	L 100
	1,2-BENZANTHRACENE	UG/L	L 5	L 5		153	25	L 50
	CHRYSENE	UG/L	L 5	L 5		153	25	L 50
	ANTHRACENE	UG/L	L 11	L 11		827	407	L 100
	PHENANTHRENE	UG/L	L 11	L 11		827	407	L 100
	PYRENE	UG/L	L 5	L 5		160	14	L 50
PESTICIDES	HEPTACHLOR	NG/L	417	L 1000	100	L 1000	L 1000	333

POLLUTANTS NOT LISTED WERE NEVER DETECTED
L-LESS THAN: N-D NOT DETECTED
PRELIMINARY DATA ONLY---TO BE VERIFIED

TABLE 8 (Continued)

PLANT 7

FRACTION	PARAMETER	UNITS	INFLUENT	EFFLUENT PRE CL.	PCNT REM.	COMBINED SLUDGE	HEAT TREATED SLUDGE	HEAT TREATMENT DECANT
PESTICIDES	HEPTACHLOR EPOXIDE	NG/L	83	83		L 1000	L 1000	83
	GAMMA-BHC	NG/L	500	500		L 1000	L 1000	167
	DELTA-BHC	NG/L	83	L 1000	100	L 1000	L 1000	L 1000
METALS	ANTIMONY	UG/L	6	3	50	1403	1047	54
	ARSENIC	UG/L	L 3	L 3		332	207	56
	BERYLLIUM	UG/L	0	3		L 10	L 10	1
	CADMIUM	UG/L	5	5		498	313	139
	CHROMIUM	UG/L	289	52	82	72667	56000	9569
	COPPER	UG/L	223	39	83	45833	35333	5701
	CYANIDE	UG/L	42	24	43	2503	278	49
	LEAD	UG/L	72	47	35	44167	6133	1701
	MERCURY	NG/L	1000	1000		205000	140500	1000
	NICKEL	UG/L	345	325	6	2733	20667	9888
	SELENIUM	UG/L	L 3	L 3		153	93	8
	SILVER	UG/L	5	1	80	177	185	27
	THALLIUM	UG/L	L 25	L 25		L 10	L 10	52
	ZINC	UG/L	619	108	83	120333	98833	32602
NON-CONV. METALS	ALUMINUM	UG/L	464	87	81	NOT RUN	NOT RUN	15523
	BARIUM	UG/L	84	23	73	NOT RUN	NOT RUN	935
	BORON	UG/L	759	787		NOT RUN	NOT RUN	1055
	CALCIUM	MG/L	74	72	3	NOT RUN	NOT RUN	308
	COBALT	UG/L	11	10	9	NOT RUN	NOT RUN	190
	IRON	UG/L	3463	407	88	NOT RUN	NOT RUN	46081
	MAGNESIUM	MG/L	20	19	5	NOT RUN	NOT RUN	70
	MANGANESE	UG/L	62	60	3	NOT RUN	NOT RUN	1104
	MOLYBOENUM	UG/L	17	15	12	NOT RUN	NOT RUN	154
	SODIUM	MG/L	131	130	1	NOT RUN	NOT RUN	164
	TIN	UG/L	23	13	43	NOT RUN	NOT RUN	391

POLLUTANTS NOT LISTED WERE NEVER DETECTED
L-LESS THAN: N-D NOT DETECTED:
PRELIMINARY DATA ONLY---TO BE VERIFIED

(Continued)

TABLE 8 (Continued)

PLANT 7

FRACTION	PARAMETER	UNITS	INFLUENT	EFFLUENT PRE CL.	PCNT REM.	COMBINED SLUDGE	HEAT TREATED SLUDGE	HEAT TREATMENT DECANT
	TITANIUM	UG/L	7	4	43	NOT RUN	NOT RUN	171
	VANADIUM	UG/L	142	132	7	NOT RUN	NOT RUN	662
	YTTRIUM	UG/L	3	3		NOT RUN	NOT RUN	18

POLLUTANTS NOT LISTED WERE NEVER DETECTED
L-LESS THAN: N-D NOT DETECTED:
PRELIMINARY DATA ONLY --- TO BE VERIFIED

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE

TABLE 9 SUMMARY OF ANALYTICAL DATA

PLANT 8

FRACTION	PARAMETER	UNITS	INFLUENT	FINAL EFFLUENT	PERCENT REMOVAL
CONVENTIONALS	BOD	MG/L	238	42	82
	TOTAL SUSP. SOLIDS	MG/L	205	69	66
	COD	MG/L	544	211	61
	OIL & GREASE	MG/L	115	14	88
NON-CONVENTIONALS	TOTAL PHENOLS	UG/L	72	13	82
	TOTAL SOLIDS	MG/L	928	746	20
	TOTAL DISS. SOLIDS	MG/L	723	677	6
	SETTLEABLE SOLIDS	ML/L	4	2	50
	TOTAL VOLATILE SOLIDS	MG/L	453	321	29
	VOLATILE DISS. SOLIDS	MG/L	309	268	13
	TOTAL VOL. SUS. SOLIDS	MG/L	144	53	63
	AMMONIA NITROGEN	MG/L	16	20	
	TOC	MG/L	119	52	56
VOLATILES	BENZENE	UG/L	2	7	
	1,1,1-TRICHLOROETHANE	UG/L	33	L 2	100
	1,1-DICHLOROETHANE	UG/L	1	L 1	100
	CHLOROFORM	UG/L	8	11	
	1,2-DICHLOROPROPANE	UG/L	1	L 1	100
	ETHYLBENZENE	UG/L	15	2	87
	METHYLENE CHLORIDE	UG/L	14	7	50
	TETRACHLOROETHYLENE	UG/L	26	1	96
	TOLUENE	UG/L	229	288	
	TRICHLOROETHYLENE	UG/L	30	0	100
ACID EXTRACT	2,4-DICHLOROPHENOL	UG/L	0	0	
	PENTACHLOROPHENOL	UG/L	18	17	6
	PHENOL	UG/L	9	1	89

POLLUTANTS NOT LISTED WERE NEVER DETECTED
L-LESS THAN: N-D NOT DETECTED:
PRELIMINARY DATA ONLY---TO BE VERIFIED

(Continued)

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

28

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
CENTERED HEAD FOR TABLES, ILLUSTRATIONS HERE

TABLE 9 (Continued)

PLANT 8

FRACTION	PARAMETER	UNITS	INFLUENT	FINAL EFFLUENT	PERCENT REMOVAL
BASE-NEUTRALS	1,4-DICHLOROBENZENE	UG/L	1	L 2	100
	FLUORANTHENE	UG/L	1	L 3	100
	NAPTHALENE	UG/L	12	L 2	100
	BIS(2-ETHLHEXYL) PHTHALATE	UG/L	33	7	79
	BUTYL BENZYL PHTHALATE	UG/L	50	4	92
	DI-N-BUTYL PHTHALATE	UG/L	2	4	
	DIETHYL PHTHALATE	UG/L	2	L 4	100
	ANTHRACENE	UG/L	2	L 3	100
	PHENANTHRENE	UG/L	2	L 3	100
METALS	CHROMIUM	UG/L	256	85	67
	COPPER	UG/L	327	108	68
	CYANIDE	UG/L	11	4	64
	LEAD	UG/L	329	85	74
	MERCURY	NG/L	350	L 200	100
	NICKEL	UG/L	427	236	45
	SELENIUM	UG/L	L 50	26	
	SILVER	UG/L	13	1	92
	ZINC	UG/L	1722	500	71
NON-CONV. METALS	ALUMINUM	UG/L	1278	474	63
	BARIUM	UG/L	537	185	66
	CALCIUM	MG/L	54	59	
	IRON	UG/L	5460	1814	67
	MAGNESIUM	MG/L	15	15	
	MANGANESE	UG/L	190	152	20
	SODIUM	MG/L	140	139	1

POLLUTANTS NOT LISTED WERE NEVER DETECTED
L-LESS THAN: N-D NOT DETECTED
PRELIMINARY DATA ONLY---TO BE VERIFIED

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
PAGE NUMBER

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE

TABLE 10 SUMMARY OF ANALYTICAL DATA

PLANT 8

FRACTION	PARAMETER	UNITS	INFLUENT	FINAL EFFLUENT	PERCENT REMOVAL
CONVENTIONALS	BOD	MG/L	113	5	96
	TOTAL SUSP. SOLIDS	MG/L	149	14	91
	COD	MG/L	267	36	87
	OIL & GREASE	MG/L	36	6	83
NON-CONVENTIONALS	TOTAL PHENOLS	UG/L	67	7	90
	TOTAL SOLIDS	MG/L	455	292	36
	TOTAL DISS. SOLIDS	MG/L	234	235	
	SETTLEABLE SOLIDS	ML/L	9	L 1	100
	TOTAL VOLATILE SOLIDS	MG/L	190	66	65
	VOLATILE DISS. SOLIDS	MG/L	54	50	7
	TOTAL VOL. SUS. SOLIDS	MG/L	131	9	93
	AMMONIA NITROGEN	MG/L	10	3	70
	TOC	MG/L	86	12	86
VOLATILES	BENZENE	UG/L	1	4	
	CARBON TETRACHLORIDE	UG/L	1	L 5	100
	CHLOROBENZENE	UG/L	L 5	1	
	1,1,2-TRICHLOROETHANE	UG/L	23	1	96
	1,1,2,2-TETRACHLOROETHANE	UG/L	1	L 5	100
	CHLOROFORM	UG/L	4	2	50
	ETHYLBENZENE	UG/L	1	1	
	METHYLENE CHLORIDE	UG/L	5	L 5	100
	METHYL CHLORIDE	UG/L	2	2	
	TETRACHLOROETHYLENE	UG/L	4	0	100
	TOLUENE	UG/L	8	0	100
	TRICHLOROETHYLENE	UG/L	33	L 5	100

POLLUTANTS NOT LISTED WERE NEVER DETECTED
L-LESS THAN: N-D NOT DETECTED:
PRELIMINARY DATA ONLY---TO BE VERIFIED

(Continued)

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-70)

TABLE 10 (Continued)

PLANT 8

FRACTION	PARAMETER	UNITS	INFLUENT	FINAL EFFLUENT	PERCENT REMOVAL
ACID EXTRACT	PARACHLOROMETA CRESOL	UG/L	2	L 50	100
	4,6-DINITRO-O-CRESOL	UG/L	L 50	0	
	PHENOL	UG/L	2	L 60	100
BASE-NEUTRALS	BIS(2-ETHYLHEXYL) PHTHALATE	UG/L	5	L 20	100
	DI-N-BUTYL PHTHALATE	UG/L	13	16	
	DIETHYL PHTHALATE	UG/L	11	2	82
METALS	ANTIMONY	UG/L	0	0	
	ARSENIC	UG/L	2	2	
	CADMIUM	UG/L	3	2	33
	CHROMIUM	UG/L	55	3	95
	COPPER	UG/L	70	26	63
	CYANIDE	UG/L	82	27	67
	LEAD	UG/L	91	17	81
	NICKEL	UG/L	38	25	34
	SELENIUM	UG/L	2	2	
	SILVER	UG/L	11	1	91
	ZINC	UG/L	160	57	64
NON-CONV. METALS	ALUMINUM	UG/L	577	98	83
	BARIUM	UG/L	115	34	70
	BORON	UG/L	145	131	10
	CALCIUM	MG/L	29	27	7
	IRON	UG/L	1505	372	75
	MAGNESIUM	MG/L	7	7	
	MANGANESE	UG/L	169	91	46
	HOLYBDENUM	UG/L	L 36	7	
	SODIUM	MG/L	46		
	TIN	UG/L	20	L 26	100
	TITANIUM	UG/L	27	6	78
	VANADIUM	UG/L	4	2	50

POLLUTANTS NOT LISTED WERE NEVER DETECTED
L-LESS THAN: N-D NOT DETECTED:
PRELIMINARY DATA ONLY---TO BE VERIFIED

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

POTW's with flows above 5 MGD, no smaller plants will be sampled, with a full spectrum of larger plants included in the project. With regard to industrial flow, POTW's ranging from zero to more than 50 percent industrial contribution will be covered. Similarly, it is anticipated that all of the 34 industrial groups currently under review by the EPA Effluent Guidelines Division that discharge to POTW's will be covered by the study. Few plants always meet the 30/30 BOD, TSS secondary treatment requirements, but POTW's are only selected if their operation is found to be reasonably good. Finally, POTW's will be selected from each EPA region. The number of plants selected will be in proportion to the total number of POTW's in that region. As a result, the more densely populated regions will have more POTW's included in the 40 plant study.

The nine plants covered in this paper are all activated sludge plants. As a result, no comparisons between treatment processes can be drawn. Nevertheless, activated sludge is a prevalent treatment process, making this partial data valuable.

Data Summary

Tables 2 through 10 present summaries of the analytical data available for the nine POTW's covered in this paper. The data base is complete for the first seven plants. At the time of this writing, no sludge data had been received for Plant 8 and Plant 9. All concentrations shown in the tables are for averages of the values obtained during the week of sampling at each plant. Similarly, the percent "removals" presented were calculated using the weekly averages.

Impact of Industrial Flow

One of the objectives of the work was to determine the impact of industrial contributions on the concentrations of priority pollutants measured at the influent to the POTW. Table 11 presents a summary of linear regression calculations to determine if there is a correlation. Since the current data base is somewhat limited with only nine plants' data included, a high degree of variability could be expected. To decrease the expected variability, instead of calculating the regression for each individual priority pollutant, regressions for the sum of various priority pollutant fractions versus percent industrial flow were calculated. As can be seen from the table, all major fractions, metals, organics, volatiles and base-neutrals, statistically increased as percent industrial flow increased. That is, for each correlation the slope of the least squares fit was always positive. For metals, organics and volatiles, the slopes were relatively steep. The base-neutrals fit was not as good or steep with a slope of only 0.25, but the tendency was still for increasing influent concentration with increasing industrial input.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

The quality of the least squares fit is described by the R^2 value shown on Table 11. The higher R^2 is, up to a maximum of 1.00, the better the fit. Although there are no R^2 values very close to unity, the R^2 values obtained are respectable considering the limited nature of the data base with only nine data points. It is expected that later evaluations of this kind using the full 40 plant data base that will be generated will produce better correlations. Nevertheless, the tendency for higher influent priority pollutant concentrations with increasing industrial flow appears to be prevalent. It should also be noted that, although not appropriate at this stage, multiple regression will be attempted on the full data base. This method is expected to provide a better description of this phenomena.

TABLE 11. LINEAR REGRESSION - INFLUENT PRIORITY POLLUTANT CONCENTRATION

Priority Pollutant Fraction	Slope	R^2	n
Metals	29.9	0.53	9
Organics	2.11	0.32	9
Volatiles	3.16	0.26	9
Base-Neutrals	0.25	0.04	9

Effect of POTW Operations on Priority Pollutant Removal and Treatment

POTW's are generally designed to reduce the concentrations of conventional pollutant parameters such as BOD, TSS and fecal coliform. Removal or treatment of other pollutants is often only incidental, by virtue of the fact that POTW's are designed to treat only a few compatible pollutants. As a result, the common assumption is that since the priority pollutants are generally incompatible with standard POTW unit operation, no appreciable reduction of these pollutants takes place. The nine plant POTW data base contradicts this assumption. In fact, for many of the priority pollutants, excellent removals were observed considering there was no deliberate operational effort made to remove these pollutants.

Figures 1 and 2 illustrate the cumulative removals and effluent concentrations observed for metals, organics and the three organic analytical fractions observed in the nine plant data base. (Note: Acid extract parameters were observed at only seven plants.) The graphs are cumulative distributors which show the percent of plants whose removal or effluent were greater than or equal to a particular value. For the organics, at least 80 percent of the plants obtained 80 percent or better removals. For the metals, 80 percent of the plants achieved roughly 60 percent removal.

Consistent Removal

The value of incidental removal of industrial priority pollutants in POTW's is that this removal may be applied to modifications of Federal categorical pretreatment standards applicable to an industrial subcategory. Credits of this sort derived from the kind of incidental removal described here may be applied to a contributing industry's discharge if certain criteria, as set forth in the General Pretreatment Regulations for Existing

FIGURE 1
CUMULATIVE DISTRIBUTION CURVES

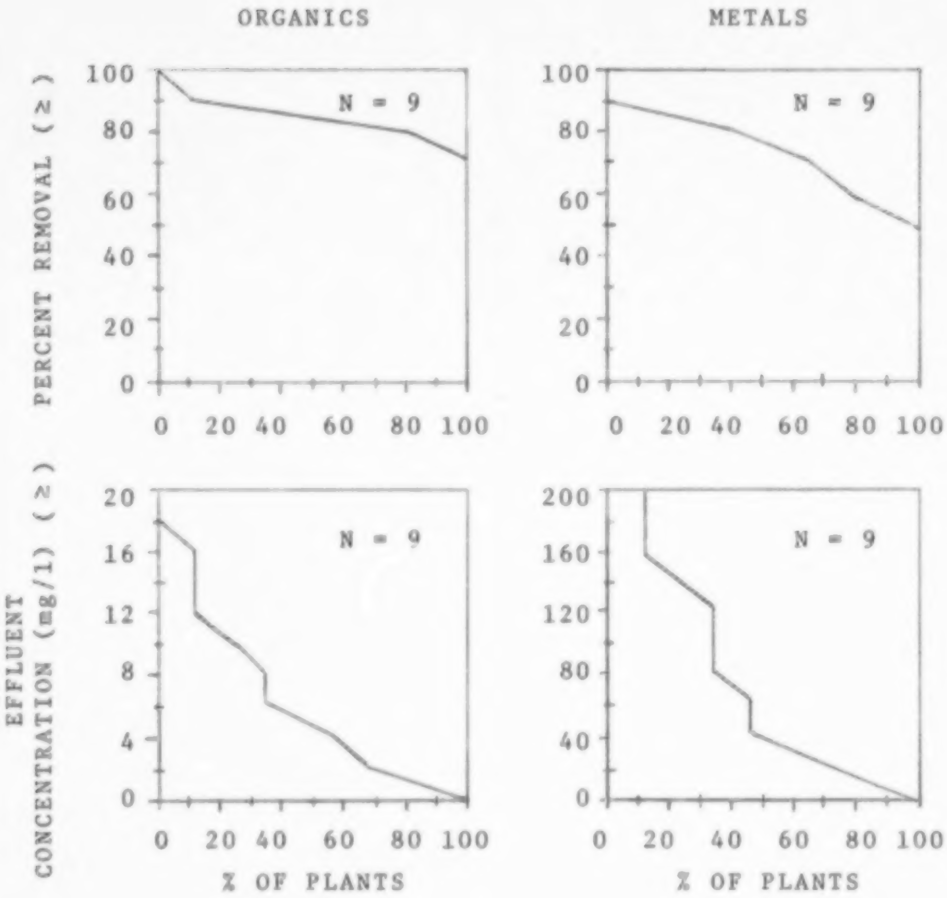
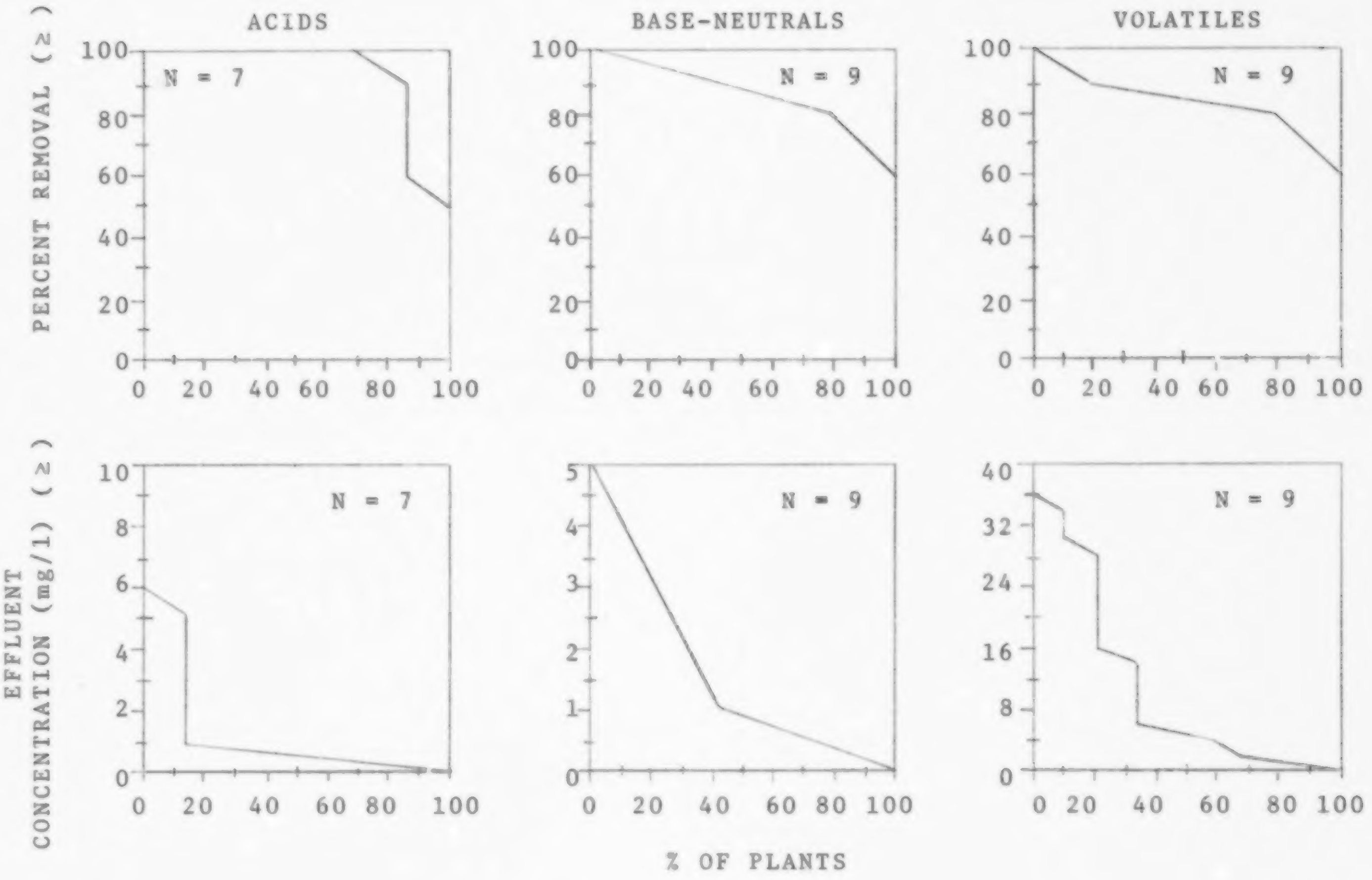


FIGURE 2
CUMULATIVE DISTRIBUTION CURVES



and New Sources of Pollution (40 CFR 403), are met. Beyond administrative requirements, such as receipt of approval to revise limits, having an approved pretreatment program and considerations regarding control of bypass events, the POTW must develop technical information in two general areas.

First, the POTW must show that the treatment plant achieves "consistent removal" of the toxic pollutant in question. In the revisions to 40 CFR 403 (October 29, 1979) EPA defines consistent removal as "the average of the lowest 50 percent of the removals measured." At least eight influent and eight effluent samples, seasonally spaced must be taken to establish the removal efficiency. More samples are preferred, but when between eight and twelve are taken, the average of the lowest six removals may be used in the determination of "consistent removal."

The POTW must also determine if the pollutant in question, after revision of the categorized standard, will interfere with plant operations in terms of excursions from NPDES permit requirements and disruption of sludge disposal pathways. The regulations state that the pollutant must not "cause or significantly contribute" to a violation of the NPDES permit for credits to be allowed. Further, the increased toxic contribution to the POTW must not cause sludge quality to exceed that required by existing regulatory requirements.

Table 12 summarizes calculated approximate "consistent removals" observed in the nine plant data base for selected priority pollutants. The parameters shown on the table are those pollutants for which EPA has promulgated categorical pretreatment standards in four industrial categories. The categories include Electroplating, Textiles, Petroleum and Leather Tanning. The "consistent removals" were calculated by averaging the lowest four removals found during the six or seven days of sampling at each plant. The table shows that considerable removal credits may be obtainable if all additional technical and administrative requirements can be met.

TABLE 12. APPROXIMATE "CONSISTENT REMOVALS" BASED ON NINE PLANT DATA BASE

Priority Pollutant	Percent Removal
Copper	42 to 91
Nickel	2 to 41
Chromium	45 to 94
Zinc	38 to 81
Lead	0 to 82
Cadmium	0 to 92
Silver	0 to 80
Cyanide	0 to 74

EPA-287 (Cin.)
(8-78)

Concentration of Priority Pollutants in the Sludge

One of the technical factors that might preclude the use of incidental removal for revision of Categorical Standards is the impact of priority pollutant removal on sludge quality. To provide some perspective on the relative importance of sludge contamination with regard to the removal of certain priority pollutant groups, Table 13 has been developed.

TABLE 13. AVERAGE CONCENTRATION FACTORS

Fraction	Primary Sludge	Combined Sludge
Volatiles	7	30
Acid	Insufficient Data	-
Base-Neutral	115	105
Metals	160	175

Table 13 presents a summary of the average concentration factors (defined as the sludge concentration divided by the influent concentration) for each priority pollutant fraction at both plants where the primary sludge was sampled (Plants 1, 5 and 6) and plants where a combined sludge stream was sampled (Plants 2, 3, 4 and 7). The averages were computed using only parameters which were consistently measured above their detection limit. This procedure eliminated several instances where parameters were not measured in the influent but were found in the sludges, which would have resulted in infinite concentration factors. The number of data points included is consequently small, and a wide variation in factors was encountered. Nevertheless, several trends appeared clear.

Volatile priority pollutants which are primarily refractory had the lowest concentration factors, consistent with the hypothesis that airstripping is a principal removal mechanism for them. Base-neutral priority pollutants showed much higher concentration factors. For example, bis(2-ethyl-hexyl)phthalate which occurred at the highest levels across most plants showed concentration factors ranging from 7 to 272, with an average of 111 and a median of 85. Metal priority pollutants had the highest concentration factors, averaging 160 in primary sludges and 175 in combined sludges.

Mass Balance

To confirm the valudity of the data base, mass balances were calculated. Table 14 summarizes the masses of priority pollutants in the influent and effluent and sludge streams at each POTW. For the most part, the influent and "total out" columns are within the same order of magnitude, and mass balances for conventional pollutant parameters show good agreement.

Several trends are indicated by the data. Volatile priority pollutants showed a median loss from the influent to the exiting streams of 72 percent, with a range of 25 to 87 percent. Base-neutral organics showed a median loss of 37 percent with a range of 0 to 78 percent. Metals in the "total

TABLE 14 MASS BALANCE (1)

Plant No.	Fraction (lb/d)	Influent	Total Out	Final Effluent	Primary Sludge	Secondary Sludge	Combined Sludge (2)
1	Organics (3)	252	122	88	28	8	
	Volatiles	183	51	41	5	5	
	Acid Extraction	14	20	17	1	2	
	Base-neutrals	55	51	30	22	1	
	Metals	820	1480	160	760	560	
2	Organics	6.8	6.5	5.2			2.1
	Volatiles	3.2	2.4	1.9			.8
	Acid Extraction	.3	1.5	1.5			.1
	Base-neutrals	3.3	2.6	1.8			1.2
	Metals	36	33	17			16
3	Organics	27	8	5			4
	Volatiles	19	5	4			1
	Acid Extraction	2	2	0			2
	Base-neutrals	6.2	1.4	.9			.6
	Metals	79	49	25			23
4	Organics	1323	376	302			73
	Volatiles	1109	315	282			34
	Acid Extraction	15	1	0			1
	Base-neutrals	199	60	20			38
	Metals	575	914	241			673
	Pesticides	.3	.2	.2			0
5	Organics	179	106	97			8
	Volatiles	171	98	96			1
	Acid Extraction	.4	.3	.1			.3
	Base-neutrals	8	8	1			7
	Metals	99	92	26			66
	Pesticides	0	.2	.2			0
6	Organics	191	27	19			8
	Volatiles	175	23	16			7
	Acid Extraction	1.6	.5	.3			.3
	Base-neutrals	14	4	3			1
	Metals	540	181	80			102
7	Organics	160	83	54			31
	Volatiles	65	23	17			7
	Acid Extraction	3.7	2.9	0			2.9
	Base-neutrals	91	57	37			21
	Metals	649	610	245			365
	Pesticides	.6	.3	.3			0

---

(1) Fraction masses to nearest pound, except where less than 1 pound, inwhich case to .1 pound. All metals and organics (total) to nearest pound.

(2) Combined sludge for Plants 4, 5 and 6 is digested combined sludge. Combined sludge for Plant 7 is heat treated combined sludge.

(3) Organics is a summation of volatiles, acid extractables, and base-neutrals.

EPA-287 (Cin.)
(4-76)

out" had a median value 7 percent lower than the influent, ranging from an 80 percent increase to a 65 percent decrease.

The mass of organic priority pollutants was approximately one-third or less than the mass of metallic priority pollutants at Plants 1, 2, 3, 6 and 7. However, at Plants 4 and 5, the relationship was reversed, with organic pollutants having roughly twice the mass of metallic priority pollutants present. At both of these plants the volatile pollutant fraction accounted for most of the organic pollutant mass measured.

SUMMARY AND CONCLUSIONS

During 1981 the full 40 POTW data base will be established. It is anticipated that this data base will be large enough to allow development of firm conclusions regarding the fate of toxic pollutants in POTW's. However, at this time, it can be preliminarily concluded that significant incidental priority pollutant removal does take plant in POTW's. Further, it is clear that influent toxic pollutant concentration increases as the amount of industrial contribution increases. The full data base should provide an opportunity to better describe removals and toxic pollutant incidence as well as other specific phenomena. In the interim, the data presented here should provide a basis for understanding the behavior of priority pollutants in POTW's.

ACKNOWLEDGMENTS

The authors would like to acknowledge the efforts of the following Burns and Roe employees who aided in the preparation of this paper: F. Thompson, H. Chen, M. Klingenstein.

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD, BEGIN SECTIONS HERE

PB83-142422

BEHAVIOR OF SELECTED TOXIC SUBSTANCES IN WASTEWATER COLLECTION AND TREATMENT SYSTEMS

A. C. Petrasek, Jr., Ph.D., P.E.
Chief, MERL Pilot Projects
Test and Evaluation Facility
U.S. Environmental Protection Agency
Cincinnati, Ohio

INTRODUCTION

Section 307 of Public Law 92-500 requires the Environmental Protection Agency to identify toxic substances and to promulgate regulations controlling the discharge of those materials from point sources. The original list of 65 toxic substances evolved from the NRDC Consent Decree (NRDC vs. Train), and has subsequently been expanded to include more than 129 specific toxics. The objective of this research effort is to provide information about the behavior of some of the toxic substances in conventional water pollution control systems.

For the purpose of research efficiency, the organic chemicals on the priority pollutant list have been segregated into two general categories; those chemicals which are volatile, which implies stripping may be a significant mechanism of removal, and those organic compounds which are semivolatile. The project discussed in this paper is studying the behavior of the semivolatile organic priority pollutants and the heavy metals.

The basic approach in this project is to operate parallel sequences of unit processes. One treatment train is operated as a control; the other sequence has the organic compounds being studied added in a toluene solution. The initial spiking provides a concentration of 50 micrograms/liter for most of the organic compounds being studied. All process flows, sludges, and offgases are sampled so that the behavior of the spiked chemicals and indigenous metals can be quantitated.

PILOT PLANT EQUIPMENT

The research apparatus being used in this project is installed at the U.S. EPA's Test and Evaluation (T&E) Facility in Cincinnati, Ohio. The T&E Facility is located on the site of the Metropolitan Sewer District's Mill Creek Sewage Treatment Plant. All of the Mill Creek STP process flows and sludges are pumped to the T&E Facility where they can be utilized as feed streams for various experimental systems. All of the process flows generated at the T&E Facility are returned to the headworks of the Mill Creek STP.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

The two existing treatment sequences have design flows of 1.5 gpm, and a simplified schematic diagram is shown in Figure 1. Raw wastewater from the Mill Creek STP is pumped at 300 gpm to the raw wastewater head tank in the T&E Facility, from this point approximately 35 gpm is diverted to the project site. The raw wastewater is first screened on a Bauer Hydrasieve to remove large particulates that could clog process piping.

The screened raw wastewater is then pumped to a manifold where the flow is split into the 1.5 gpm treatment sequence influents. The spike solution is added to the experimental train with a metering pump immediately after the flow is split.

The sewer simulator consists of 84 feet of 3-inch steel pipe on a seven percent grade, which provides a 4.5 foot per second velocity with the pipe half-full at 50 gpm. A sump and recirculation pump provide a 73-minute detention time at the design flow of 1.5 gpm.

The aerated grit chambers were designed to simulate the stripping associated with the process. The units are stainless steel drums that provide a theoretical residence time of 15 minutes and receive air flows of 25-30 scfh.

The primary clarifiers are 3-foot diameter stainless steel units with a 5-foot SWD. The clarifiers have a 45-degree cone on the bottom and sludge collectors that operate at 5 rph. Design overflow rate and weir loading are 305 gpd/ft^2 and 243 gpd/ft., respectively.

The activated sludge process consists of stainless steel aeration basins and secondary clarifiers, which are identical to the primary clarifiers. The design residence time in the 5 pass aeration basins is 7.5 hours. The units are 2-ft. wide, 10-ft. long, and have a 4.5 ft. SWD. Typical air flows are 20 scfm.

All process piping is either steel, cast iron, or stainless steel to avoid any possibility of organic contamination. The feed and return sludge pumps are Moyno progressive cavity with Buna-N stators and chromed rotors.

SYSTEM OPERATION

General

The data in Table 1 are a summary of six months of operation of the A and B treatment sequences on the semivolatile priority pollutant research project. When considered in terms of the more conventional water quality parameters, the treatment has been excellent, more importantly the A and B trains are providing almost identical results.

During this period the mean reductions observed for TSS, COD, and TOC were 95, 89, and 89 percent, respectively. The average effluent TSS concentration was 30 mg/l, which corresponded to a mean turbidity of 25 NTU.

EPA-287 (Cin.)
(4-76)

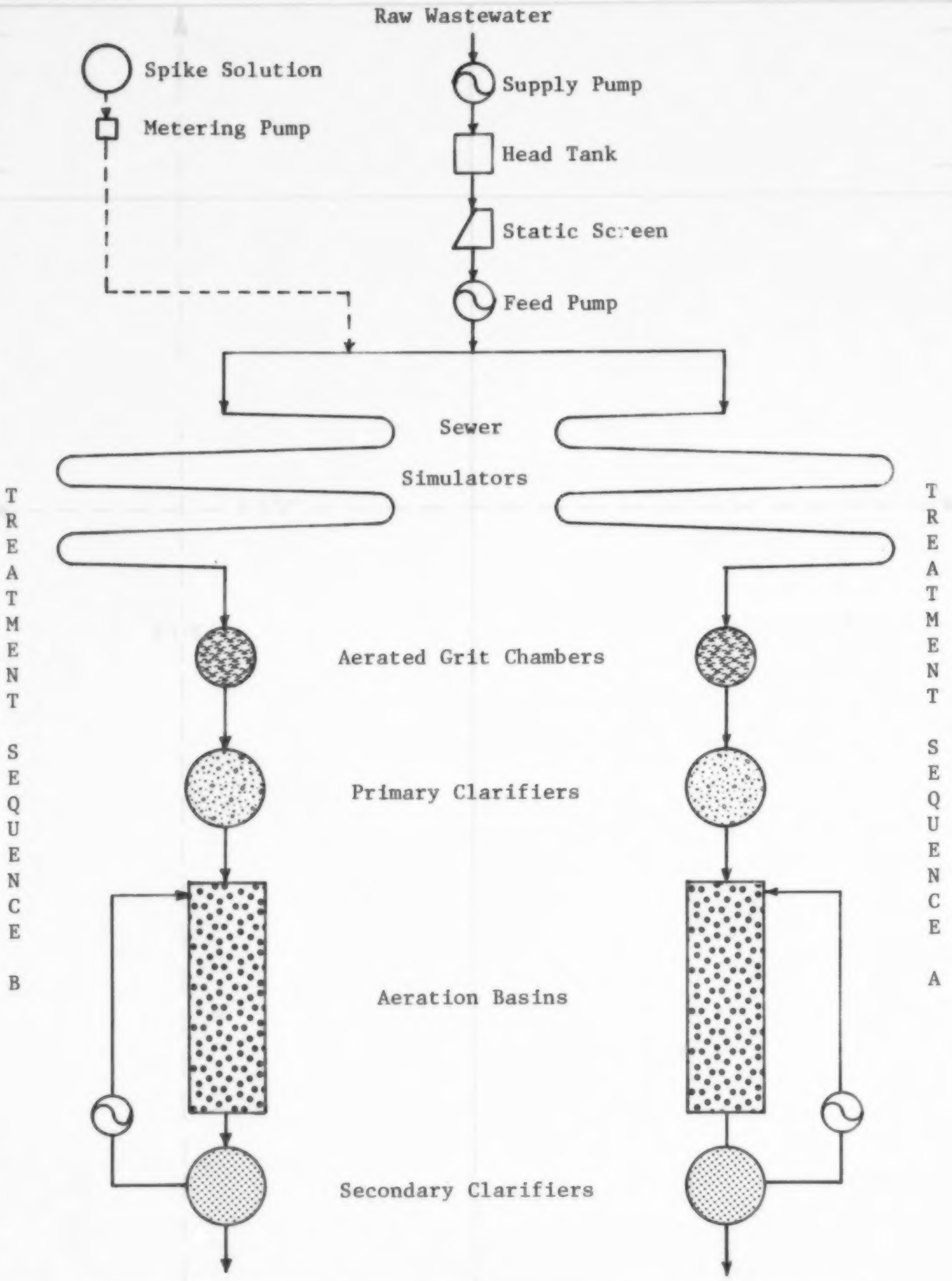

Raw Wastewater
Spike Solution
Supply Pump
Metering Pump
Head Tank
Static Screen
Feed Pump
Sewer
Simulators
TREATMENT SEQUENCE B
TREATMENT SEQUENCE A
Aerated Grit Chambers
Primary Clarifiers
Aeration Basins
Secondary Clarifiers

Figure 1. Simplified Schematic Diagram: Nonvolatile Priority Pollutant Project

EPA-287 (Cin.)
(4-76)

TABLE 1. SUMMARY OF CONVENTIONAL TREATMENT SEQUENCES A & B

OCTOBER 1979 thru MARCH 1980

Parameter	Sequence Influent (mg/1)		Primary Effluent (mg/1)		A.S. Effluent (mg/1)		Total Removal (percent)	
	A	B	A	B	A	B	A	B
TSS	607	576	310	383	30	31	95	95
COD	741	748	443	410	86	83	88	89
TOC	214	210	138	127	23	24	89	89
Total P	9.0	8.6	6.4	6.1	3.1	3.1	66	64
TKN	40.6	39.5	34.1	34.4	11.4	8.5	72	79
NH_3-N	21.0	21.2	19.8	18.9	6.5	4.4	69	79
NO_2 & NO_3-N	0.1	0.1	0.1	0.2	5.2	5.8	-	-
Total N	40.7	39.6	34.2	34.6	16.6	14.3	59	64
Alkalinity (as $CaCO_3$)	-	-	298	291	203	180	-	-
Turbidity (NTU)	-	-	96	96	25	25	-	-

Static Screen

The Hydrasieve effected a 57.5 percent reduction in TSS, which resulted in a mean TSS concentration of 592 mg/l in the screened product. The Hydrasieve has proved to be reasonably effective in preventing plugging of the 3/4-inch and 1-inch lines in the subsequent unit processes.

Sewer Simulators

No significant changes occurred in the conventional water quality parameters that can be attributed to this process, with the exception of ammonia nitrogen. During the six-month period the mean concentration of ammonia nitrogen decreased by 1.3 mg/l in the A sequence and 2.2 mg/l in the B sequence. This corresponds to a 9.4 percent reduction for the A train and a 10.4 percent decrease in the B system. The reductions can be attributed to stripping in the simulated sewer.

Aerated Grit Chamber

As expected, the two aerated grit chambers did not make any significant changes in the conventional water quality parameters during the first six months of operation.

Primary Clarifiers

The primary clarifiers have provided good treatment during the first six months of operation. Total suspended solids reductions averaged 53.2 percent for the A unit and 45.3 percent for the B system. COD reductions for the A and B system averaged 51.2 and 51.4 percent, respectively; and the mean TOC reductions were 48.1 for the A system and 49.2 percent for the B primary clarifier. During this portion of the study the primary clarifier effluent quality was as shown in Table 1.

Activated Sludge Processes

Both of the activated sludge processes provided good treatment during the first six months. After initial start-up the processes were operated in a nitrifying mode for three months. At that time it was decided that non-nitrifying operation was more typical of municipal treatment plants, and the processes were shifted to non-nitrifying operation. Both processes have operated well on the relatively strong Mill Creek wastewater. Typical respiration rates in the mixed liquor range from 45 to 90 mg-hr/l.

INORGANIC WATER QUALITY

Combined municipal/industrial nonconsumptive water use increases the pollutant load in Cincinnati rather substantially as the data in Table 2 indicate. The column headed Process Influent is the means of 15 weekly composite samples of the screened raw wastewater entering the control sequence (treatment sequence A). Data for the City of Cincinnati drinking water are averages for calendar years 1974 through 1978, with the exception of certain metals data which are averages for calendar year 1978.

TABLE 2. INCREASE IN MEAN CONCENTRATIONS DUE TO MUNICIPAL/INDUSTRIAL USE

Metal	Process ^{3} Influent (mg/1)	Cinti. Drinking Water (mg/1)	Increase (mg/1)
As *	< 20	5^1	< 19.5
Ag *	<2.7	0.00^1	< 2.7
Ca	80	45^2	35
Cd *	29.9	0.000^1	29.9
Cr	0.50	0.002^1	0.50
Cu	0.74	-	-
Fe	3.65	0.30^2	3.35
Hg *	-	0.1^1	-
Mg	18.7	9.2^2	9.5
Mn	0.62	0.00^2	0.62
Ni	0.30	-	-
Pb	0.95	0.006^1	0.95
Zn	1.25	-	-
TDS	-	251^2	-
SO_4	289	83^2	206
SiO_2	54	$4\text{-}7^2$	49±
Cl	250	28^2	222
F	0.6	0.30^2	0.28

* - micrograms/liter
1 - average for 1978
2 - average for 1974-1978
3 - average of 15 weekly composites

EPA-287 (Cin.)
(4-76)

The SiO_2 increase of 49 mg/l is notable, as are the sulfate and chloride increases of 206 mg/l and 222 mg/l, respectively. Substantial increases in Cd, Cr, Fe, Mg, Pb, Mn, and Zn are apparent. The Mill Creek interceptor, which runs generally north up the Mill Creek valley, serves the preponderance of the major industry in Cincinnati and the water quality data confirm that fact.

Since November 1, 1979, twenty weekly composite samples were collected for metals determinations. The sampling was performed on the control sequence A (unspiked), and all samples were acidified with two milliters of concentrated nitric acid. The results obtained to date are presented in Tables 3 through 11. The data for mercury and arsenic have not been presented because the metals concentrations were below the detection limit in virtually all samples.

Silver

Silver was present at concentrations below the detection limit in a substantial number of samples at all sampling points; therefore, percent reduction data are of only limited utility. The data in Table 3 indicate the primary clarifier was somewhat effective in reducing the silver concentration, and that the activated sludge process had no measurable effect on the concentration of silver.

Cadmium

Cadmium was only slightly reduced in concentration by the primary clarifier (26 percent); however, the activated sludge process removed over 87 percent of the cadmium. Both the sewer simulator and aerated grit chamber had no significant effect on Cd concentrations. Figure 2 shows the Cd concentrations observed in the influent, primary clarifier effluent, and activated sludge effluent.

Chromium

Neither the sewer simulator, aerated grit chamber, or primary clarifier had any significant effect on the observed Cr concentrations. The activated sludge process did reduce the mean Cr concentration by 0.34 mg/l, or 72 percent. The Cr concentrations observed at selected sampling points are shown in Figure 3.

Copper

The only unit process to significantly alter the observed Cu concentrations was the activated sludge process. The observed mean decrease was 0.76 mg/l, or 92 percent. Figure 4 presents some of the Cu data, and there are notable variations, particularly in the primary clarifier effluent. The high values for the standard deviation and variance confirm that observation.

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD. BEGIN SECTIONS HERE

TABLE 3. OBSERVED SILVER CONCENTRATIONS
WEEKLY COMPOSITE SAMPLES
NOV. 1, 1979 to MARCH 21, 1980

Sample Location	Number of Analyses	Arith. Mean	Std. Deviation	Variance
Influent	20	<2.7	2.296	5.010
Sewer Simulator Effluent	19	<2.6	1.894	3.402
Grit Chamber Effluent	19	<2.4	2.090	4.138
Primary Effluent	20	<1.5	0.889	0.750
Activated Sludge Effluent	20	<1.6	0.754	0.540

TABLE 4. OBSERVED CADMIUM CONCENTRATIONS
WEEKLY COMPOSITE SAMPLES
NOV. 1, 1979 to MARCH 21, 1980

Sample Location	Number of Analyses	Arith. Mean	Std. Deviation	Variance
Influent	20	29.9	16.69	264.49
Sewer Simulator Effluent	20	22.7	12.51	148.63
Grit Chamber Effluent	19	28.4	17.60	293.51
Primary Effluent	20	21.0	19.37	356.40
Activated Sludge Effluent	20	2.7	1.92	3.51

BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
BEGIN LAST LINE OF TEXT

EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD, BEGIN SECTIONS HERE

TABLE 5. OBSERVED CHROMIUM CONCENTRATIONS WEEKLY COMPOSITE SAMPLES NOV. 1, 1979 to MARCH 21, 1980

Sample Location	Number of Analyses	Arith. Mean	Std. Deviation	Variance
Influent	20	0.50	0.423	0.170
Sewer Simulator Effluent	20	0.50	0.285	0.077
Grit Chamber Effluent	20	0.57	0.374	0.133
Primary Effluent	20	0.47	0.353	0.119
Activated Sludge Effluent	20	0.13	0.143	0.019

TABLE 6. OBSERVED COPPER CONCENTRATIONS WEEKLY COMPOSITE SAMPLES NOV. 1, 1979 to MARCH 21, 1980

Sample Location	Number of Analyses	Arith. Mean	Std. Deviation	Variance
Influent	20	0.74	0.265	0.067
Sewer Simulator Effluent	20	0.76	0.263	0.066
Grit Chamber Effluent	19	0.88	0.319	0.096
Primary Effluent	20	0.86	0.640	0.389
Activated Sludge Effluent	20	0.10	0.051	0.003

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS

EPA-287 (Cin.)
(4-78)

TABLE 7. OBSERVED IRON CONCENTRATIONS
WEEKLY COMPOSITE SAMPLES
NOV. 1, 1979 to MARCH 21, 1980

Sample Location	Number of Analyses	Arith. Mean	Std. Deviation	Variance
Influent	20	3.65	2.072	4.077
Sewer Simulator Effluent	20	4.11	2.235	4.746
Grit Chamber Effluent	19	4.97	3.139	9.333
Primary Effluent	20	2.42	1.483	2.090
Activated Sludge Effluent	20	0.94	0.983	0.918

TABLE 8. OBSERVED MANGANESE CONCENTRATIONS
WEEKLY COMPOSITE SAMPLES
NOV. 1, 1979 to MARCH 21, 1980

Sample Location	Number of Analyses	Arith. Mean	Std. Deviation	Variance
Influent	20	0.62	0.167	0.027
Sewer Simulator Effluent	20	0.63	0.162	0.025
Grit Chamber Effluent	19	0.69	0.194	0.036
Primary Effluent	20	0.57	0.214	0.044
Activated Sludge Effluent	20	0.44	0.121	0.014

TABLE 9. OBSERVED NICKEL CONCENTRATIONS
WEEKLY COMPOSITE SAMPLES
NOV. 1, 1979 to MARCH 21, 1980

Sample Location	Number of Analyses	Arith. Mean	Std. Deviation	Variance
Influent	20	0.30	0.130	0.026
Sewer Simulator Effluent	19	<0.29	0.137	0.028
Grit Chamber Effluent	20	<0.28	0.093	0.008
Primary Effluent	20	<0.25	0.073	0.005
Activated Sludge Effluent	20	<0.21	0.022	0.0005

TABLE 10. OBSERVED LEAD CONCENTRATIONS
WEEKLY COMPOSITE SAMPLES
NOV. 1, 1979 to MARCH 21, 1980

Sample Location	Number of Analyses	Arith. Mean	Std. Deviation	Variance
Influent	19	0.953	0.448	0.190
Sewer Simulator Effluent	19	1.005	0.414	0.163
Grit Chamber Effluent	18	1.044	0.498	0.235
Primary Effluent	19	0.684	0.572	0.310
Activated Sludge Effluent	20	0.052	0.033	0.001

EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD, BEGIN SECTIONS HERE

TABLE 11. OBSERVED ZINC CONCENTRATIONS
WEEKLY COMPOSITE SAMPLES
NOV. 1, 1979 to MARCH 21, 1980

Sample Location	Number of Analyses	Arith. Mean	Std. Deviation	Variance
Influent	20	1.25	0.608	0.352
Sewer Simulator Effluent	20	1.25	0.645	0.396
Grit Chamber Effluent	19	2.10	1.750	2.900
Primary Effluent	20	1.23	1.387	1.828
Activated Sludge Effluent	20	0.41	0.229	0.050

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

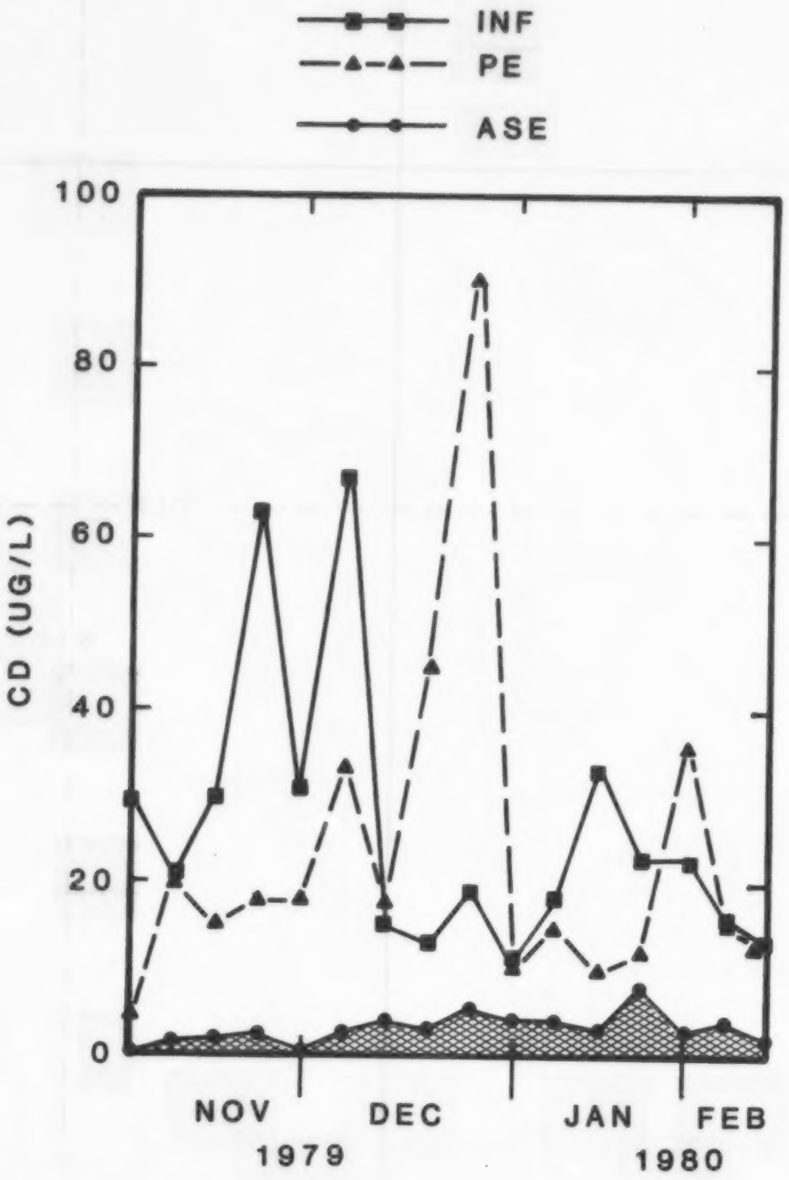


Figure 2. Observed Cadmium Concentrations

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER
EPA-287 (Cin.)
4-76)

TYPING GUIDE SHEET

BEGIN FIRST LINE OF TEXT HERE

CENTER OF PAGE

TOP OF IMAGE AREA

DROPPED HEAD: BEGIN SECTIONS HERE

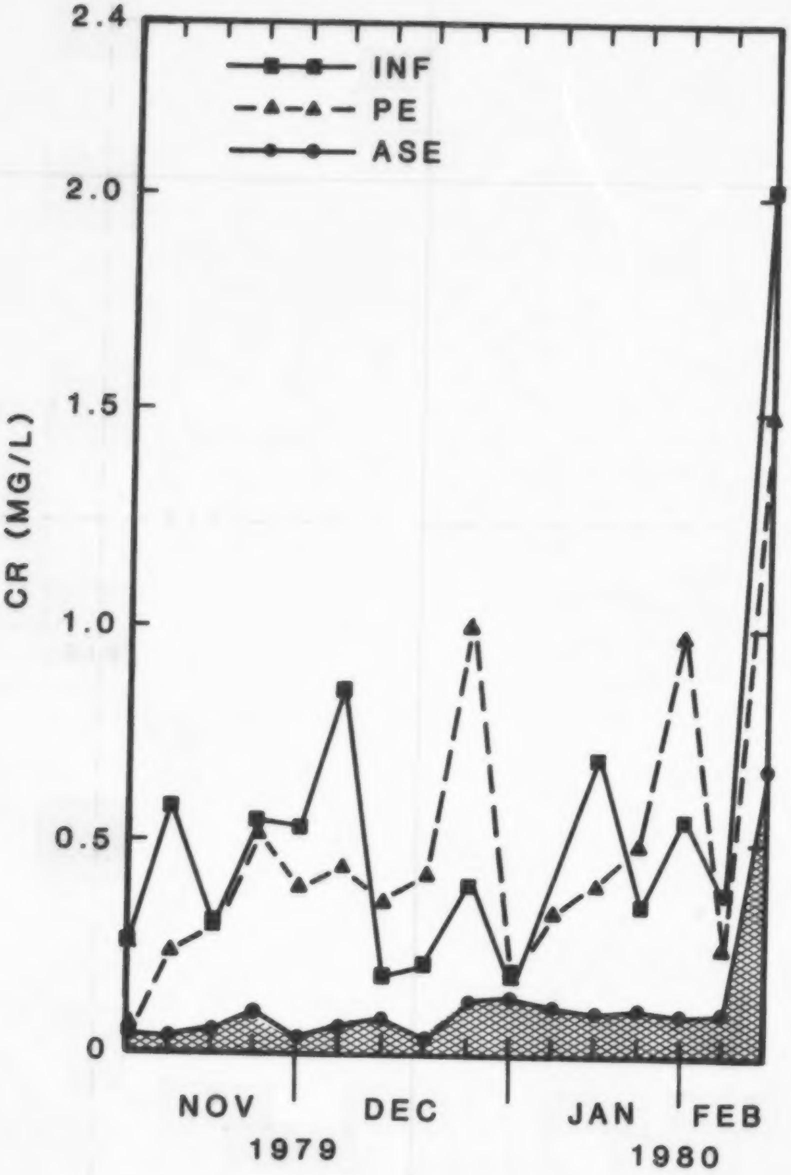


Figure 3. Observed Chromium Concentrations

BEGIN LAST LINE OF TEXT

BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS

3/8"

PAGE NUMBER

EPA-287 (Cin.)
(1-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD. BEGIN SECTIONS HERE

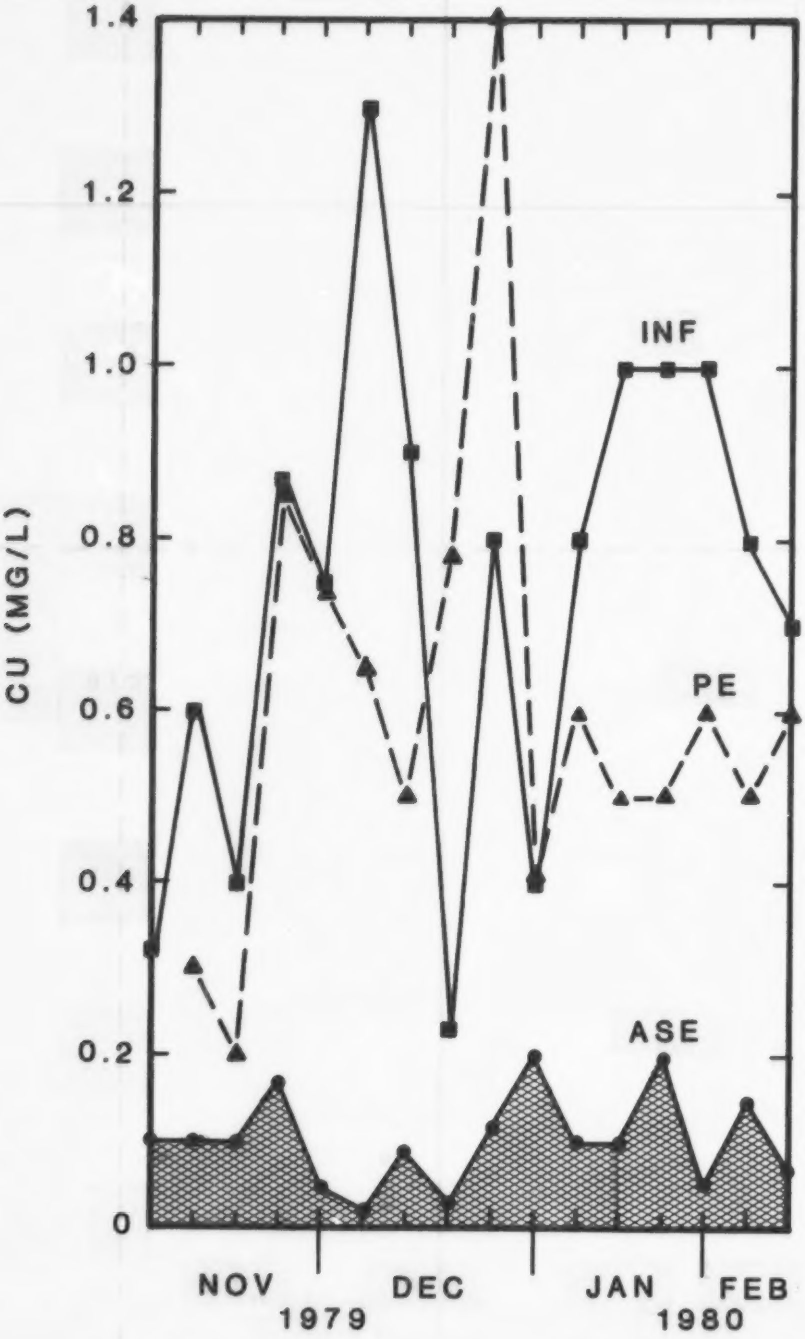


Figure 4. Observed Copper Concentrations

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

Iron

Both the primary clarifier and the activated sludge process were instrumental in reducing Fe concentrations, as the data in Table 7 and Figure 5 indicate. The standard deviation and variance were relatively high for observed Fe concentrations at all sample locations, and the activated sludge process did not do a consistent job of limiting Fe concentrations.

Manganese

The data for manganese are summarized in Table 8. As expected, none of the unit processes/unit operations were particularly effective in limiting observed Mn concentrations.

Nickel

A significant number of analyses for nickel were below the detection limit, as the less than values in Table 9 indicate. Additionally, no process significantly changed the observed mean concentrations of Ni.

Lead

Table 10 summarizes the data for lead. The activated sludge process, and to a lesser degree the primary clarifier, were effective in removing lead from the wastewater flows. The data shown in Figure 6 illustrate how effective the biological process can be in controlling transient Pb concentrations.

Zinc

The data for Zn are shown in Table 11 and Figure 7. The activated sludge process was reasonably effective in damping the observed Zn concentrations. The reason for the increase in Zn in the grit chamber effluent is unknown at this time.

Metals Removal Summary

The observed metals removals for the primary clarifier and activated sludge process are presented in Table 12. The removal values are computed on the basis of the previously discussed mean concentrations, and calculations based on median or model concentrations will clearly yield different results. Additionally, the presently available data base consists of only 20 values per metal per sample location. These data are too limited to permit the formulation of any definitive conclusions; nevertheless, they do provide valuable perspective.

The primary clarifier appears to provide significant removals for Fe, Pb, and Zn. However, the Zn concentrations in the influent to the primary clarifier (grit chamber effluent) seem questionable. If either the influent or sewer simulator effluent concentrations were used in the calculation, the Zn removal observed in the primary clarifier would be zero.

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

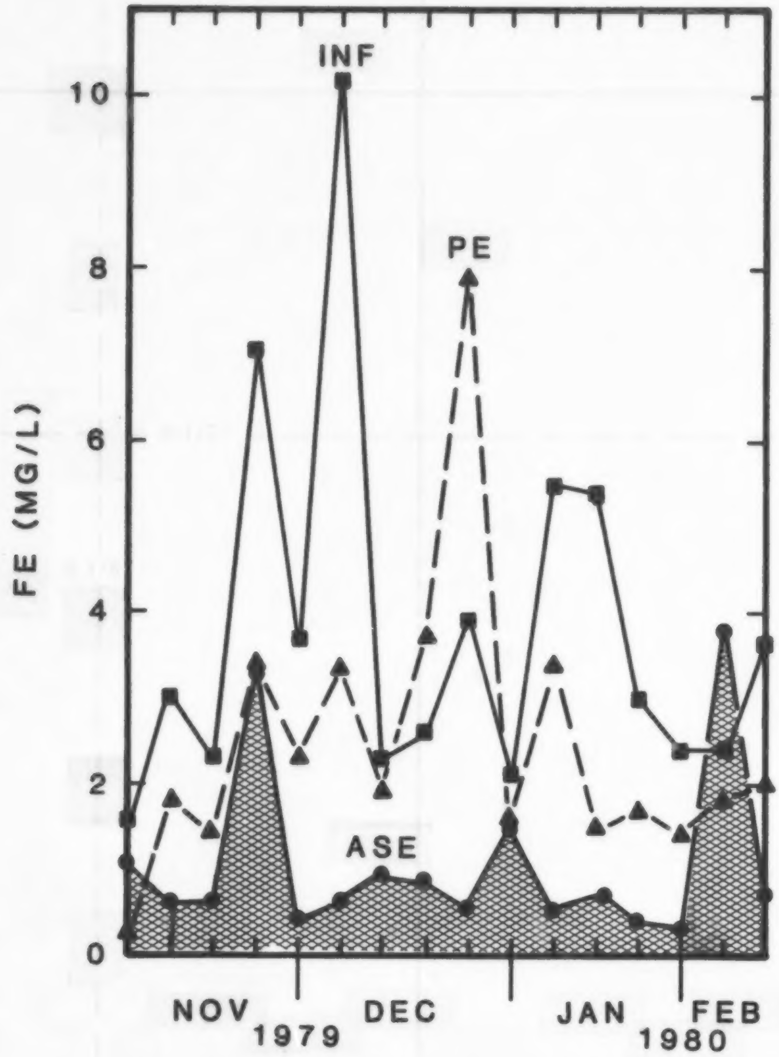


Figure 5. Observed Iron Concentrations

BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
BEGIN LAST LINE OF TEXT
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD, BEGIN SECTIONS HERE

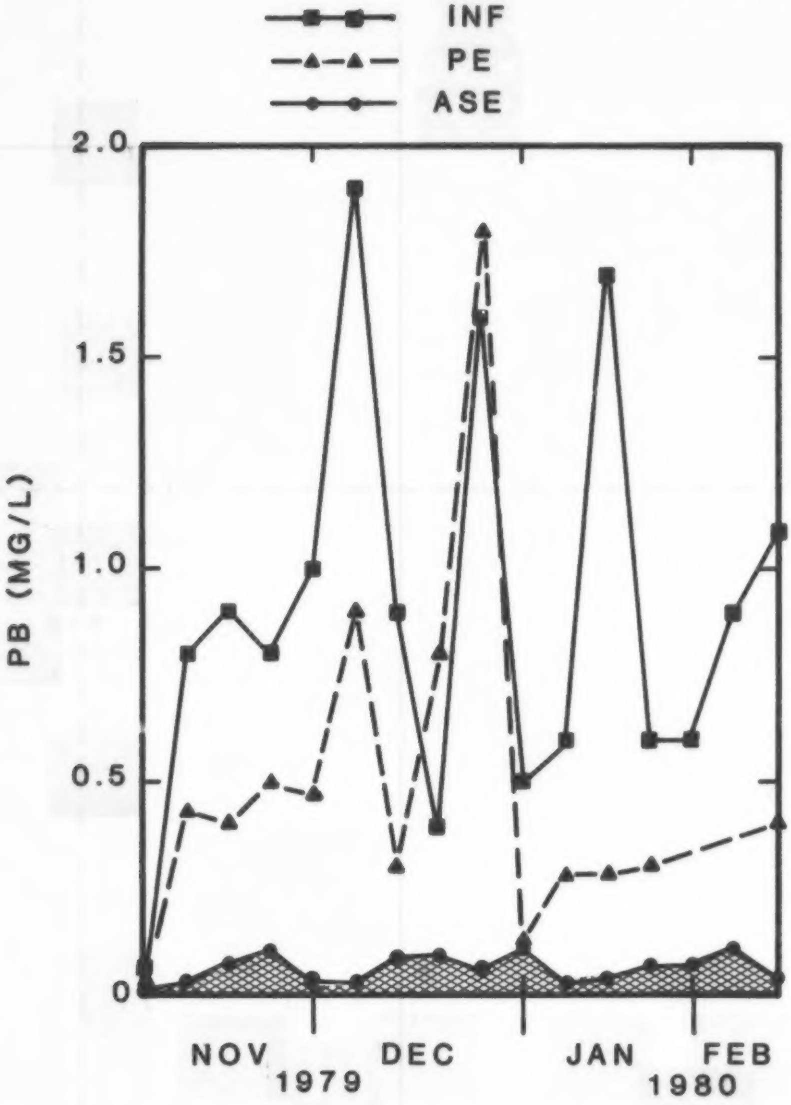


Figure 6. Observed Lead Concentrations

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

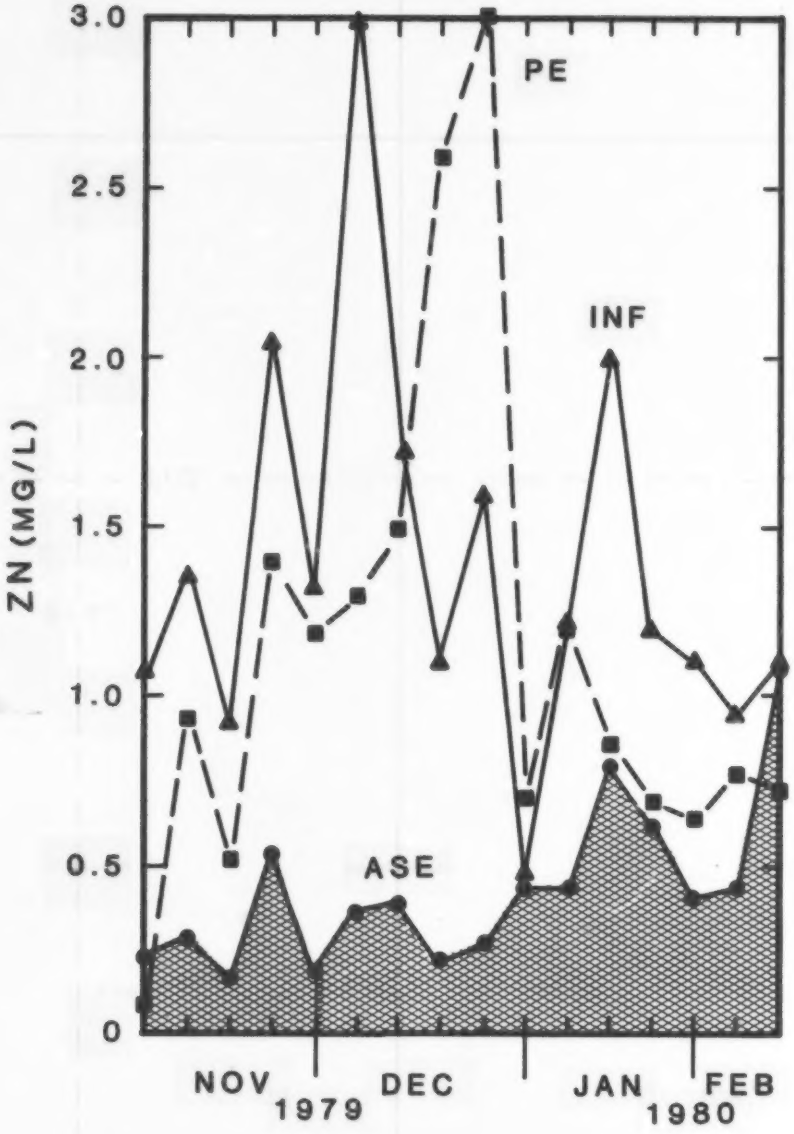


Figure 7. Observed Zinc Concentrations

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

TABLE 12. OBSERVED METALS REMOVALS

METAL	Observed Metal Removal (Percent)	
	Primary Clarifier	Activated Sludge
Ag	37.5 *	0 *
As	n.d.	n.d.
Cd	26.1	87.1
Cr	17.5	72.3
Cu	2.3	88.4
Fe	51.3	61.2
Hg	n.d.	n.d.
Mn	17.4	22.8
Ni	10.7 *	16.0 *
Pb	34.5	92.4
Zn	41.5	66.7

n.d. - majority of analyses were below detection limit

* - reported, but of limited statistical reliability due to high number of analyses below the detection limit

EPA-287 (Cin.)
(4-76)

Cd, Cr, Cu, Fe, Pb, and Zn all appear to be removed relatively effectively by the activated sludge process. Table 13 presents metals removals observed in activated sludge processes in this study conducted in Cincinnati, and in two previous projects conducted in Dallas, Texas. The Dallas data come from a two and one-half year study of metals removals by AWT processes[1], and a six-month drinking water reuse study.[2] The activated sludge process at Dallas was a completely-mixed system with a four-hour residence time, and an average flow of about 200 gpm. Although the differences in the two activated sludge systems (Cincinnati and Dallas) are considerable, the data indicate the same general pattern with respect to metals removals. Ag, As, Mn, and Ni are not significantly affected, while Cd, Cr, Cu, Fe, Pb, and Zn are all substantially reduced.

The concentration of the metal in the influent to the process will greatly affect the observed reductions, and Table 14 presents the mean influent concentrations for both the Cincinnati and Dallas based research. Some rather significant differences exist, especially notable are Cr, Cu, Fe, Mn, Pb, and Zn.

ORGANIC PRIORITY POLLUTANTS

The initial set of organic compounds selected for study are given in Table 15. The components are present in a toluene solvent, and are pumped into the influent of the experimental treatment sequence (sequence B). Most compounds are spiked at an initial concentration of 50 micrograms/liter, with the exceptions of bis(2-ethylhexyl) phthalate which is spiked at 100 micrograms/liter and Arochlor 1254 and Toxaphene which are at 150 micrograms per liter.

The first set of 24-hour composite samples for GC-MS analysis was collected on January 6, 1980. Partial results are shown in Table 15. All of the samples were extracted, concentrated, and cleaned-up in the laboratory operated by the Waste Analysis and Identification Section (WA&IS), Technology Development and Support Branch, Wastewater Research Division, Municipal Environmental Research Laboratory, Cincinnati, Ohio. The GC-MS analyses were performed by the WA&IS laboratory and by the Toxicants Analysis Laboratory, National Space Testing Laboratory, U.S. EPA, Bay-St. Louis, Mississippi.

To date sufficient samples have not been processed to permit calculation of recovery factors for each compound in the various wastewater and sludge matrices; therefore, the reported concentrations are uncorrected with respect to recovery factors.

The data available for the primary effluents indicate that recoveries range from 70 to 90 percent for the PAH's, from 70 to 100 percent for the phthalates, from 95 to 100 percent for the phenols, and from 90 to 100 percent for the pesticides.

The data in Table 15 are only preliminary, but they indicate that the conventional treatment processes should be reasonably effective in removing the PAH's and to a lesser extent the phthalates. There are too few data,

TABLE 13. METALS REMOVAL BY ACTIVATED SLUDGE PROCESSES

Metal	Cincinnati[1] Study	Dallas[2] Metals Study	Dallas[1] Reuse Study
Ag	0*	51*	n.d.
As	n.d.	9	19
Cd	87	49	58
Cr	72	65	65
Cu	88	68	74
Fe	61	43	9
Mn	23	26	42
Ni	16*	25	n.d.
Pb	92	54	53
Zn	67	62	44

n.d. - not detected or not run

* - reported, but of limited statistical reliability due to high number of analyses below the detection limit

1 - acidified weekly composite samples

2 - acidified daily composite samples

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE

TABLE 14. OBSERVED MEAN METALS CONCENTRATIONS IN ACTIVATED SLUDGE PROCESS INFLUENTS

Metal	Cincinnati (mg/l)	Dallas (mg/l)
Ag*	<1.5	0.78
As*	< 20	14.8
Cd*	21	14
Cr	0.47	0.21
Cu	0.86	0.22
Fe	2.42	1.07
Mn	0.57	0.08
Ni	<0.25	0.11
Pb	0.68	0.11
Zn	1.23	0.37

* - micrograms per liter

BEGIN LAST LINE OF TEXT
3/8"
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TABLE 15. PARTIAL RESULTS* FOR SAMPLES OF JAN. 6, 1980

Compound	Control Sequence			Experimental Sequence		
	Inf. (μg/l)	Pri. Eff. (μg/l)	A.S. Eff. (μg/l)	Spiked Inf. (μg/l)	Pri. Eff. (μg/l)	A.S. Eff. (μg/l)
Acenaphthene	1.4	5.0	-	47.0	36.1	-
Anthracene	10.2	4.0	-	37.5	29.4	-
Benzo(a)anthracene	-	-	-	46.6	20.8	0.7
Chrysene	-	-	-	46.6	20.8	0.7
Fluoranthene	2.6	-	-	44.3	29.4	-
Fluorene	20.0	4.5	-	56.2	40.6	-
Ideno(1,2,3,cd)pyrene	-	-	-	-	-	-
Naphthalene	34.5	18.7	-	75.2	40.7	-
Phenanthrene	10.0	4.0	-	37.5	29.4	-
Pyrene	1.4	-	-	44.5	27.1	2.9
Bis(2-ethylhexyl)phthalate	23.6	50.8	-	76.8	198.7	7.4
Butyl benzyl phthalate	2.9	4.3	-	38.9	101.6	0.4
Di-n-butyl phthalate	6.2	-	-	43.2	83.5	1.1
Diethyl phthalate	4.4	4.5	-	57.0	108.4	0.4
Dimethyl phthalate	-	-	-	50.2	67.7	-
Di-n-octyl-phthalate	1.3	-	-	45.1	74.5	1.0
2,4 - dimethyl phenol	32.2	-	n.a.	58.7	63.2	n.a.
Pentachlorophenol	-	17.5	n.a.	190.	158.	n.a.
Phenol	122.	-	n.a.	316.	176.	n.a.
Arochlor 1254	-	-	n.a.	-	-	n.a.
Endosulfan I and II	-	-	n.a.	-	-	n.a.
Heptachlor	78.7	-	n.a.	63.2	38.4	n.a.
Lindane	14.2	-	n.a.	56.5	61.0	n.a.
Toxaphene	-	-	n.a.	-	-	n.a.

* Values reported have not been corrected for recovery factors

n.a. - No analysis

- Not detected

with too much variability, to make any statement relevant to either the phenols or the pesticides.

An additional seven or eight samples will be collected for GC-MS analysis with the present set of compounds in the spike solution. This should provide an adequate data base from which relatively meaningful statistical observations can be made. At the conclusion of this study a different set of organic compounds will be selected for future studies. Additionally, two more parallel, 1.5 gpm treatment sequences will be brought on-line in early summer. The added sequences will permit either the study of three different sets of compounds with a control or studying the same set of compounds at three different concentrations.

The volatile compounds will be investigated using apparatus with a design flow of 35 gpm, in which the aeration basins have a SWD of 12 feet. This equipment will more closely approximate stripping in an actual treatment plant than would the 1.5 gpm systems which have an aeration basin SWD of 4.5 feet. The large-scale apparatus to be used in the volatile priority pollutant studies is scheduled for start-up in early July 1980.

REFERENCES

Petrasek, A. C., Jr., and Rice, I. M. "Water Reuse Research." Proceedings of the AIChE-EPA Complete Reuse Symposium, Cincinnati, Ohio, June 1976.

Petrasek, A. C., Jr. Wastewater Characterization and Process Reliability for Potable Wastewater Reclamation, Report No. EPA-600/2-77-210, Municipal Environmental Research Laboratory, U.S. EPA, Cincinnati, Ohio, November 1977.

EFFECT OF COMBINED TREATMENT ON PRIORITY POLLUTANTS IN POTW'S

F. B. DeWalle
D. A. Kalman
Department of Environmental Health
University of Washington
Seattle, WA 98195

E. S. K. Chian
Department of Civil Engineering
Georgia Institute of Technology
Atlanta, GA 30332

INTRODUCTION

Recent studies have shown the widespread presence of trace contaminants in the environment. Through improved analytical methodologies, trace compounds can now be detected routinely at the parts per billion, and sometimes at the parts per trillion level.

The present study evaluated the efficiency of different treatment processes to remove trace contaminants from wastewater. Since considerable quantities of industrial chemicals are discharged into municipal sewers, the study evaluated removal efficiencies in plants receiving variable amounts of industrial contributions. The treatment processes remove these contaminants from the liquid wastestream and accumulate them on the solids leaving the process such as primary sludge, waste activated sludge, and anaerobic digested sludge. The other major removal step is volatization.

ANALYTICAL METHODOLOGY

The analytical scheme used in the current study detects organics with a wide range of physical-chemical properties ranging from very volatile organics, such as chloromethane, to the more hydrophobic compounds, such as polychlorinated biphenyls (PCB's).

Development of the list of priority pollutants, which also includes 13 metals and asbestos and cyanide, for a total of 129 individual compounds, resulted from the suit, NRDC vs. Train (U.S. EPA), forcing the EPA to define toxic and hazardous waste materials and to establish discharge requirements for each of these materials.

EPA-287 (Cin.)
(8-76)

Detailed pretreatment regulations, yet to be published, will include priority pollutant discharge limits for individual industrial groups, including POTW's. The discharge limits will be incorporated into the new generation of NPDES permits that will be developed for virtually all permitted dischargers over the next five-year period.

The analytical scheme uses an acid methylene chloride extraction, bio-beads S-X2 separation to remove lipids, florisil clean-up to remove hydrocarbons and a cesium silicate fractionation to remove phenols from neutral compounds (Figure 1). The compounds are subsequently screened by GC and identified by GC/MS analysis using a 30m x 0.25mm SE-54 capillary column directly coupled to the mass spectrometer.

PRIORITY POLLUTANTS IN SEWAGE AND SLUDGE

The present study sampled 25 POTW's receiving different percentages of their waste stream from industrial dischargers. Among the volatile organics, trichloroethene was found at the highest concentration while the highest median values were noted for dichloromethane, tetrachloroethene, methylbenzene, and 1,4-dichlorobenzene. A typical frequency distribution curve for the benzenes in the incoming sewage at the POTW (Figure 2) shows a variability of three orders of magnitude. As these aromatic compounds adsorb onto the suspended solids in sewage, they are removed during primary sedimentation. The accumulation ratio, i.e. the concentration in the sludge divided by the sewage concentration, of the benzenes generally ranges from 1 to 1,000 resulting in an even greater concentration variability among plants (Figure 3). Among the different priority pollutant fractions, the largest accumulation was noted for phthalates and polynuclear aromatic hydrocarbons (Figure 4). The nitroamines may well be formed in the digester in the presence of nitrified sludge and amino acids. Very little accumulation of the volatile chlorinated C_1 and C_2 compounds is noted.

The total concentration of organic priority pollutants was also observed to be dependent on the percent contribution of industrial wastes in each treatment plant (Figure 5). This relationship also suggests that potential for control exists.

It was observed that the chlorinated C_1-C_2 compounds, the Cl/aklyl benzenes, and phenols all exhibit fairly strong dependence on percent industrial waste flow. Total phthalate concentrations, on the other hand, appear to be essentially independent of the fraction of industrial waste flow. These data suggest that industrial pretreatment may be effective for reducing concentrations of the solvent substances in phenols, but may not be effective for control of certain classes of compounds, such as the phthalates.

REMOVAL EFFICIENCIES OF PRIORITY POLLUTANTS

When the discharge of priority pollutants is difficult to control at the source, the POTW becomes the only alternative to prevent these compounds from entering the environment. Variable removal efficiencies have been observed at the POTW for different types of organics.

The limited data show that the removal of the total priority pollutant load was about 48 percent during primary treatment and 61 percent during secondary treatment. This corresponds to a BOD removal of 36 percent and TSS removal of 67 percent during primary treatment and a BOD removal of 95 percent and TSS removal of 97 percent during secondary treatment. The lower than expected removal during secondary treatment is due to the inability to substantially remove a few of the priority pollutants, such as methylene chloride and dichlorobenzene, are formed during the chlorination process.

The removal efficiency of the priority pollutants during the primary sedimentation process is likely due to the adsorption of the organics onto the solid particles and the subsequent removal of these particles by sedimentation. As the extent of adsorption increases with increasing molecular weight of the organic compounds, the organic removal efficiency of the primary treatment step was found to increase with higher molecular weights.

The removal efficiency of the secondary treatment process employing activated sludge is due to bacterial degradation, adsorption onto the biomass and volatilization during the aeration step. The highest removal observed for the chlorinated C_1-C_2 is likely due to the volatilization of these compounds.

Likely compounds of those found that may be formed in the chlorine disinfection process are methylene chloride, 1,2-dichlorobenzene, and 1.4-dichlorobenzene. Relatively low removals were observed for tetrachloroethylene and pentachlorophenol, possibly indicating their low adsorption potential and resistence to bacterial breakdown.

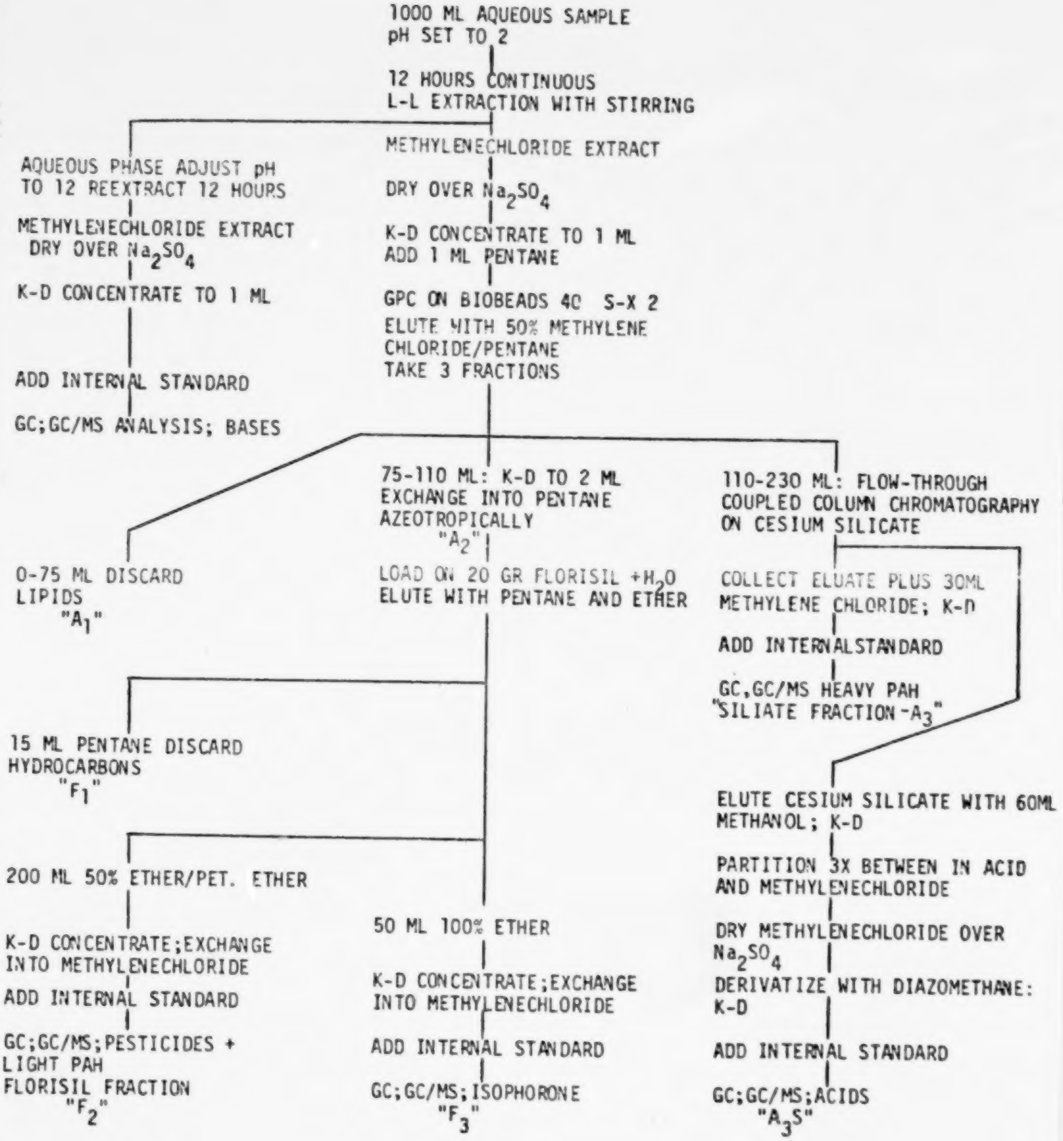
Toxicity testing of the POTW effluent (Figure 6) using the TA-100 *Salmonella typhimurium* strain showed no presence of mutagenic activity, due to the masking toxicity effect. The evaluation of the individual fraction showed that the highest toxicity resulted from the non-extractable organics remaining in the aqueous layer, indicating that further research using membrane and HPLC techniques to concentrate and separate these organics is required before reuse of waste water can be considered.

SUMMARY AND CONCLUSIONS

Analysis of the current data shows increasing amounts of total organic priority pollutants detected in sewage with increasing plant flow and percentage industrial contribution.

Industrial pretreatment control would probably be effective for chlorinated solvents, Cl/alkyl benzenes, and phenols but not for phthalates. When source control is not practical due to the large number of discharge points and low volume, removal of the compounds at the sewage treatment plant becomes of prime importance. Primary treatment is effective in removing high molecular weight compounds that adsorb onto the solids that are removed during sedimentation. Secondary treatment is able to remove compounds that are volatile through air stripping in the aeration basin. Additional adsorption onto the bacterial solids occurs in the sludge aeration basins; adsorbable organics will accumulate in the primary and secondary sludge and thus pose a solids disposal problem. Source control, if practicable, should receive the highest priority in controlling the discharge and proliferation of compounds in the environment.

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE


1000 ML AQUEOUS SAMPLE
pH SET TO 2
12 HOURS CONTINUOUS
L-L EXTRACTION WITH STIRRING
METHYLENECHLORIDE EXTRACT
DRY OVER Na_2SO_4
K-D CONCENTRATE TO 1 ML
ADD 1 ML PENTANE
GPC ON BIOBEADS 40 S-X 2
ELUTE WITH 50% METHYLENE
CHLORIDE/PENTANE
TAKE 3 FRACTIONS
AQUEOUS PHASE ADJUST pH
TO 12 REEXTRACT 12 HOURS
METHYLENECHLORIDE EXTRACT
DRY OVER Na_2SO_4
K-D CONCENTRATE TO 1 ML
ADD INTERNAL STANDARD
GC;GC/MS ANALYSIS; BASES
0-75 ML DISCARD
LIPIDS
"A_1"
75-110 ML: K-D TO 2 ML
EXCHANGE INTO PENTANE
AZEOTROPICALLY
"A_2"
LOAD ON 20 GR FLORISIL +H_2O
ELUTE WITH PENTANE AND ETHER
110-230 ML: FLOW-THROUGH
COUPLED COLUMN CHROMATOGRAPHY
ON CESIUM SILICATE
COLLECT ELUATE PLUS 30ML
METHYLENE CHLORIDE; K-D
ADD INTERNALSTANDARD
GC,GC/MS HEAVY PAH
"SILIATE FRACTION-A_3"
15 ML PENTANE DISCARD
HYDROCARBONS
"F_1"
ELUTE CESIUM SILICATE WITH 60ML
METHANOL; K-D
PARTITION 3X BETWEEN IN ACID
AND METHYLENECHLORIDE
200 ML 50% ETHER/PET. ETHER
K-D CONCENTRATE;EXCHANGE
INTO METHYLENECHLORIDE
ADD INTERNAL STANDARD
GC;GC/MS;PESTICIDES +
LIGHT PAH
FLORISIL FRACTION
"F_2"
50 ML 100% ETHER
K-D CONCENTRATE;EXCHANGE
INTO METHYLENECHLORIDE
ADD INTERNAL STANDARD
GC;GC/MS;ISOPHORONE
"F_3"
DRY METHYLENECHLORIDE OVER
Na_2SO_4
DERIVATIZE WITH DIAZOMETHANE:
K-D
ADD INTERNAL STANDARD
GC;GC/MS;ACIDS
"A_3S"

Modified Cleanup Scheme for Acid and Neutral Organics

Figure 1.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA

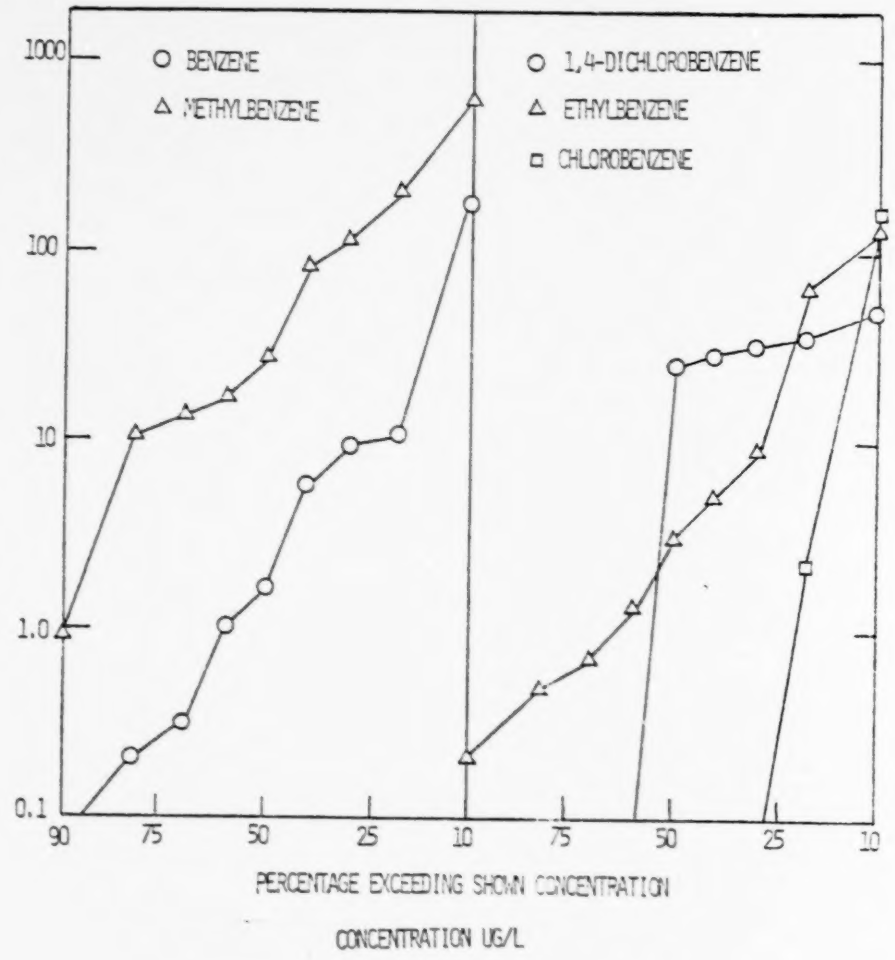


Figure 2.

BEGIN LAST LINE OF TEXT

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
DROPPED HEAD; BEGIN SECTIONS HERE
CENTER OF PAGE
TOP OF IMAGE AREA
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
EPA-287 (Cin.) (4-76)

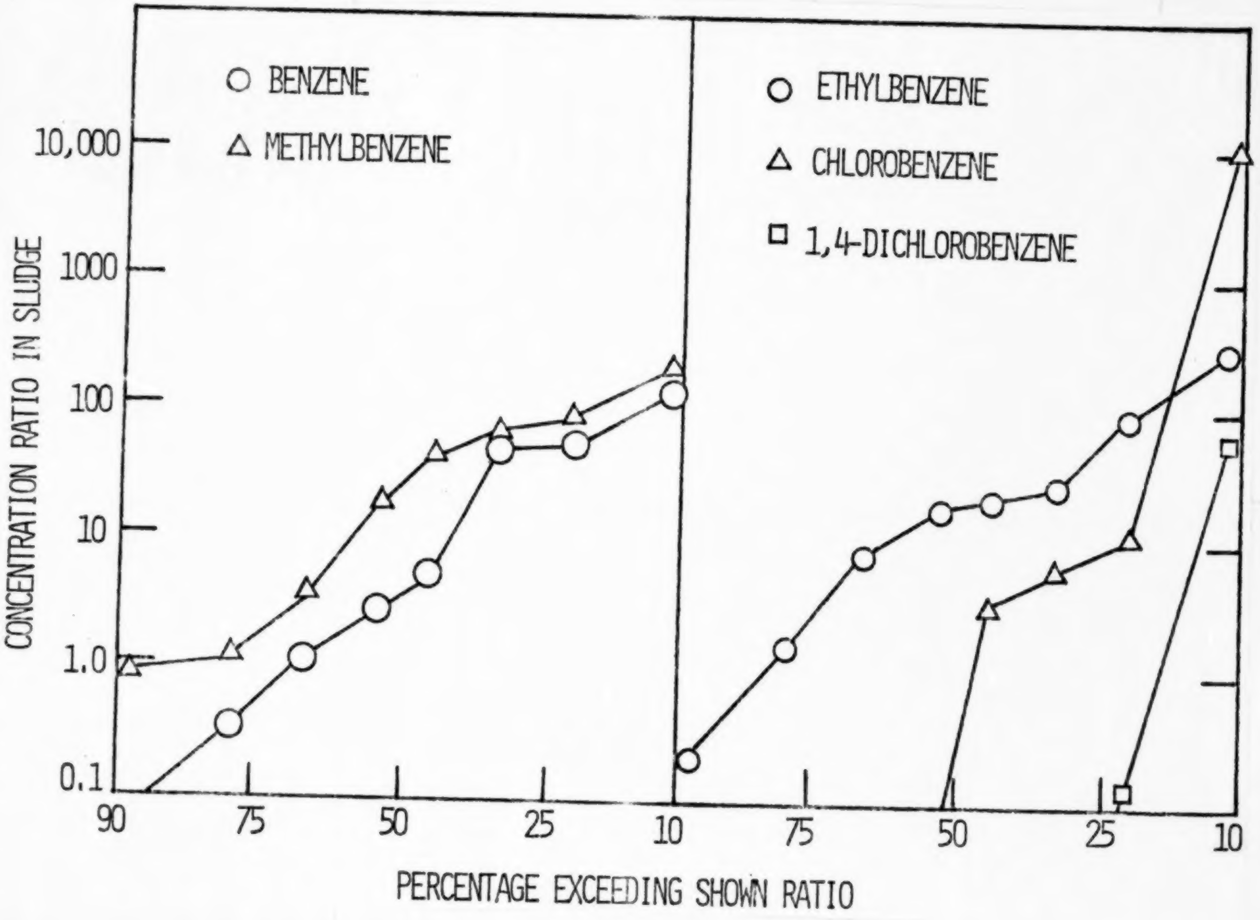
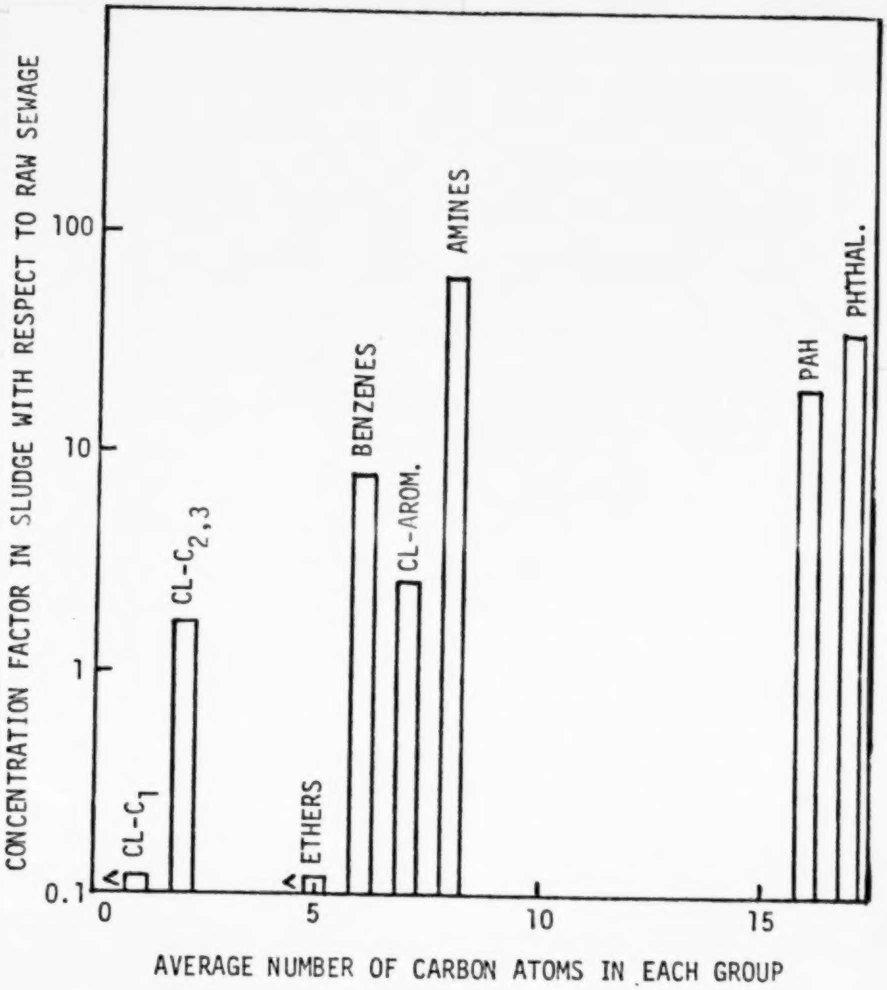


Figure 3.

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE



Bioaccumulation of Compounds in Different Fractions

Figure 4.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

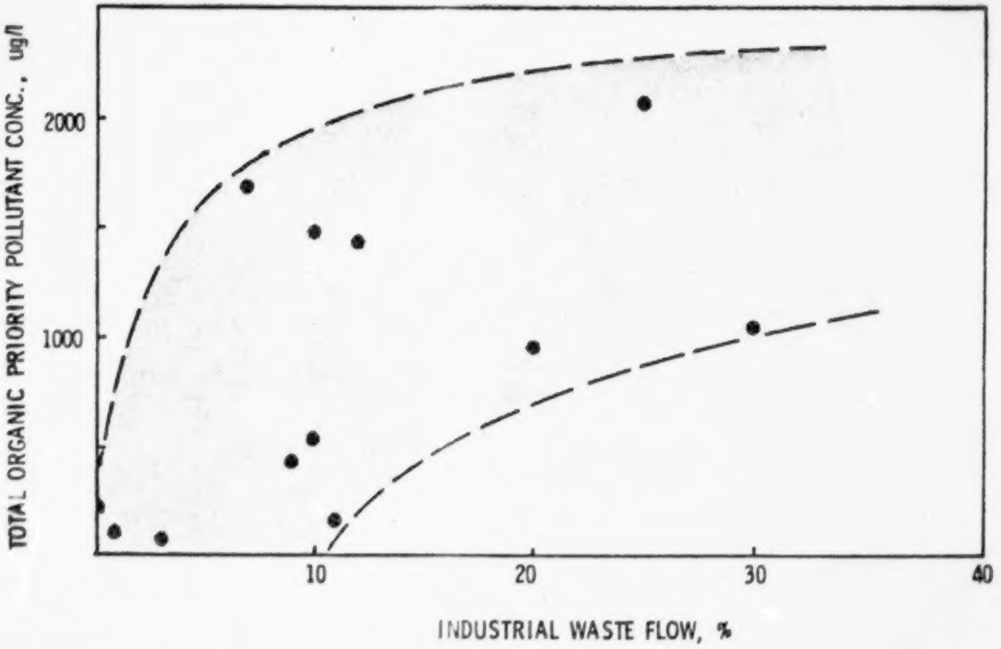
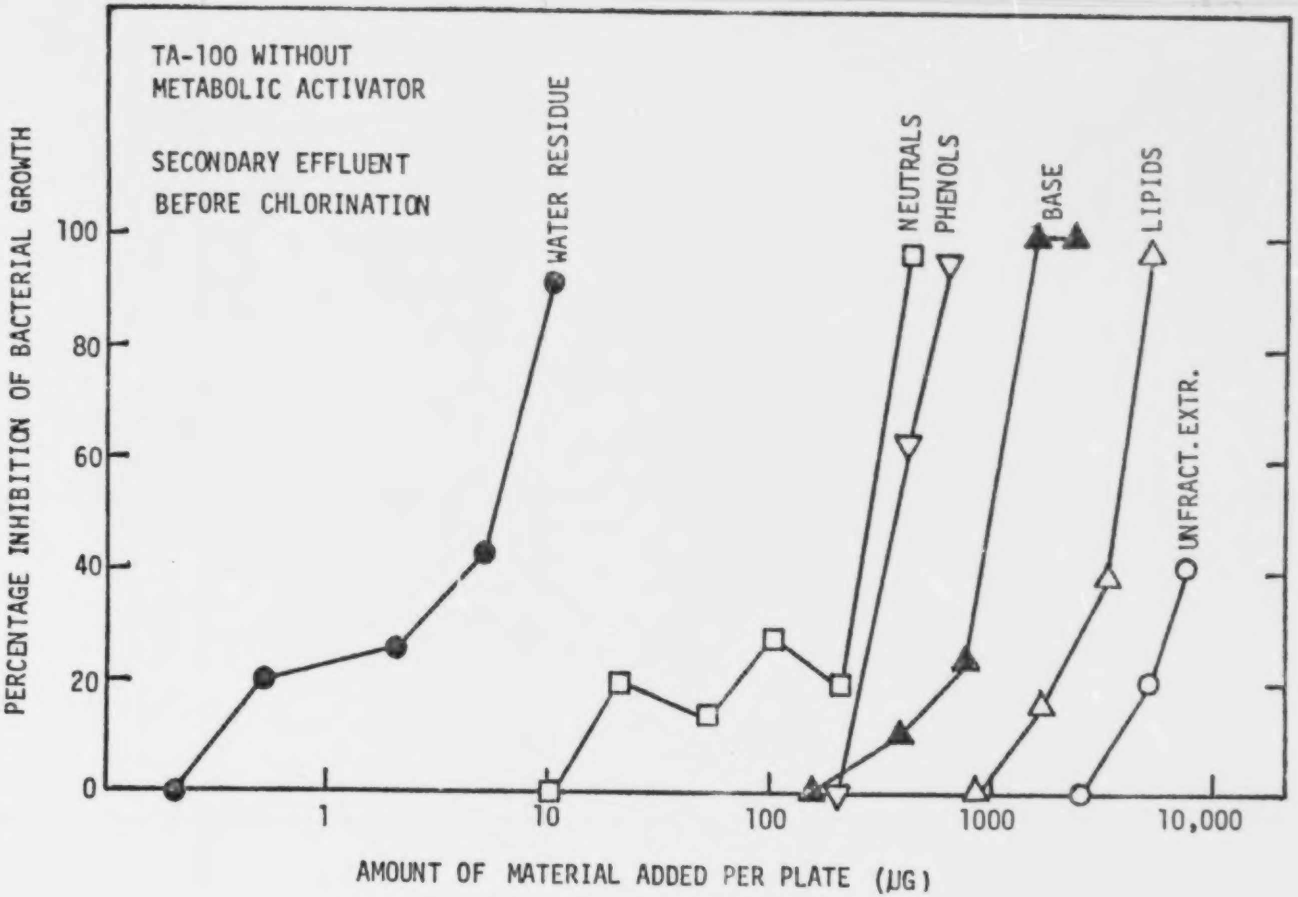

TOTAL ORGANIC PRIORITY POLLUTANT CONC., ug/l
2000
1000
10
20
30
40
INDUSTRIAL WASTE FLOW, %

Figure 5.



Toxicity of Different Fractions Present in Secondary Effluent Before Chlorination.

Figure 6.

PB83-142448

HEAVY METALS IN MUNICIPAL WASTEWATER TREATMENT PLANT INFLUENTS: AN ANALYSIS OF THE DATA AVAILABLE FROM TREATMENT PLANTS

R.A. Minear, M.W. Cantrell, R.L. Church
Department of Civil Engineering
The University of Tennessee
Knoxville, Tennessee 37916

S.A. Hannah
USEPA - MERL-WRD
Cincinnati, OH 45268

R.O. Ball
Roy F. Weston, Inc.
Weston Way
West Chester, PA 19380

ABSTRACT

The preliminary results of a 2-year study involving the identification and assembly of a data base existing within the Publicly Owned Treatment Works (POTW) of the U.S. on influent heavy metals is presented. The general character of the data base with respect to associated descriptors (among which are % industrial contribution, % combined sewers, % infiltration/inflow, sample frequency, sample type, analytical method) is provided. Wastewater treatment plant laboratories were evaluated in the conduct of the study and generally found to be satisfactory within the framework of the evaluation method. Of the 80,000 individual pieces of data from 239 wastewater treatment plants, a substantial data base was generated for cadmium, chromium, copper, nickel, lead and zinc. Extensive data (but reduced in total volume) were obtained for silver, arsenic and mercury. Limited data were obtained for beryllium, cobalt, antimony and selenium. Aluminum, iron and manganese data were received well. Median and mean (computed in varying manner) are reported and compared. While no associations could be demonstrated between the median or mean values for the composite data base and the individual descriptors using Pearson and Spearman techniques, isolation of the low percent industrial waste category from the parent data base did show a significant differences for 6 of 7 metals. Lead was the metal not showing a difference.

INTRODUCTION

A study has been conducted over the last two years in which municipal wastewater treatment facilities have been surveyed to determine which plants

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE

possess data on heavy metals concentrations in their plant influent. The study objectives were as follows:

1. Determine the extent and character of the national data base for publicly owned treatment works (POTW) influent metals concentration.

2. Provide an indication of the quality of the data base via direct laboratory evaluation.

3. Obtain and computerize a representative sampling of the defined data base in conjunction with an array of descriptors for the data source.

4. Summarize the quantitative character of the data base and examine variations relative to the array of descriptors obtained.

This paper will report on items 1 to 3 above that define the characteristics of the data base assembled and present some of the preliminary examinations of the data base (item 4).

PROCEDURE

The initial phase of the research was to determine which cities did in fact possess data on raw sewage metal concentrations at the treatment plant inlet. While some information was obtained from Regional EPA and State agency officials, most of the information obtained was by direct telephone contact with individual cities. In addition to cities and contact names provided by EPA and State agencies, an arbitrary population limit of 25,000 was set and all cities with this population or greater were listed. In total, 900 cities were selected for contact. Based on 1970 Rand McNally data, these cities represented a total population of 84,197,837 or roughly 41% of the United States population.

Affirmative responses to the question of whether or not heavy metals were assayed in the plant influent were followed up with a simple mail form that contained the information recorded from the telephone contact. The cities were asked to verify the information recorded. From the telephone survey, 444 cities gave indication of influent metals data. Of these, 287 operated their own POTW and 157 contributed to regional plants. The mail follow-up of these responses generated a slightly different picture. Now 262 cities (representing 347 individual treatment plants) indicated influent heavy metals data were obtained.

The second phase of the research was to obtain actual data from all cities willing to provide data. Because of variations in the amount of data available from each city and physical limitations in the anticipated computer coding of the data, requests for data were based on the frequency of analysis as follows:

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS

EPA-287 (Cin.)
(4-76)

Frequency of Analysis	Data Requested
≥ 50/yr.	1 year
> 10 but < 50/yr.	2 years
≤ 10/yr.	4 years or what was available

The requests for data determined that 88 cities that had reported influent data were available, measured metals only in the plant effluent. Ultimately, data were received from 154 cities representing 239 individual treatment plants. Sixteen additional cities promised data but did not send even after repeated telephone follow-ups.

DATA BASE CHARACTERISTICS

Table 1 presents the distribution of plants supplying data by EPA region. Clearly, the data base is dominated by regions III, IV, V and IX. Nine states did not supply data. These were Alaska, Idaho, Maine, Nebraska, New Mexico, North Dakota, South Dakota, West Virginia and Wyoming. Of these, only South Dakota reportedly had 1 city with data which were not sent.

States which had large numbers of plants with data were as follows:

California	32 plants
New York	18 plants
North Carolina	15 plants
Tennessee	14 plants
Indiana	13 plants
Illinois	11 plants
Virginia	11 plants
Pennsylvania	10 plants
Massachusetts	10 plants

Contrasted with an earlier study by Burns and Roe (1), this data base represented 41 states compared with 20 by the earlier study which had its data base heavily concentrated in Connecticut, Kentucky, New Jersey, Pennsylvania and Wisconsin. On the other hand, the earlier study represented 269 individual treatment plants and thus likely had greater representation from cities with a population of less than 25,000.

Descriptors

Information was sought in conjunction with the data supplied regarding the nature of the sample taken, frequency of sampling (implicit in data supplied), type of analytical procedures used, and whether or not analysis was done in-house. Furthermore, plants were requested to supply information regarding industrial contribution to the influent (both on a % flow and % of BOD basis) and the sewer system characteristics. The latter consisted of estimates of percent of combined sewers (nearest 10%), percent of flow attributable to stormwater (nearest 10%) and the magnitude of infiltration and inflow (3 categories only, <25%, 25 to 100%, >100%). Tables 2-9 summarized these descriptors in terms of the number of treatment plants in each for the particular descriptor for each of the individual metals for which data have been supplied.

The first observation from these data is that the dominant metals measured are cadmium, chromium (total), copper, nickel, lead and zinc, all with over 200 plants measuring. Silver, arsenic, iron, mercury and manganese represent an intermediate group with aluminum, cobalt and selenium showing much lower numbers of plant measuring. The balance of the metals represented in Tables 2-6 are measured by so few plants that one cannot say that a useful data base exists.

The dominant treatment plant type making influent measurements is an activated sludge plant (Table 2). For those 6 elements measured by large numbers of treatment plants, weekly sampling generally is most common with monthly sampling a close second followed, again closely, by daily sampling (Table 3). For silver, arsenic, mercury and selenium, most of those plants measuring did so monthly and, to a lesser extent, quarterly. By far, the greatest number of plants made measurements on a 24-hr. composite sample, although a significant number failed to report sample type (Table 4). Seven-day and 30-day composite samples would correspond to weekly and monthly sampling frequencies while 24-hr. composite samples could also apply to those sampling frequencies. Of importance is that the majority of samples are composites and flow proportioning was the most common practice.

By far, the dominant analysis method was atomic absorption spectrophotometry as is illustrated in Table 5. Plant visits confirmed this observation. When wet chemistry or Hach kit measurements were employed, they were generally used for relatively few metals, most commonly copper and chromium.

Most of the data represent analyses conducted by analysts at the treatment plant or a central municipal laboratory rather than by commercial laboratories (Table 6).

The distribution of plants by industrial flow contribution (Table 7) presents a reasonable spread with appreciable representation in the 0 to 4% category. For those metals measured by a large number of treatment plants, the 10 to 19% and 20 to 39% categories dominate. Relatively few treatment plants handle greater than 60% industrial waste as might be expected. These data do not differentiate with respect to industrial type, although in many cases information was supplied regarding dominant industrial contributions. This issue will be of significance in examining metals concentration in relation to industrial flow. Tables 8 and 9 show distributions of plants with respect to combined sewers and infiltration and inflow, respectively. Each of these factors relates to effects that climatological variations may have on influent metals concentrations and these effects may work opposite to other influences with subsequent obliteration of apparent relationships between metal concentrations and system descriptors. For most metals, roughly half of the plants reported zero percent combined sewers with the balance distributed among the other three (arbitrary) ranges but predominantly in the 60 to 100% category.

Laboratory Quality Index

Of the 154 cities represented by the 239 treatment plants, 140 (91%) were visited and their laboratories evaluated using a modification of a procedure contained in an EPA report, "Evaluation of Environmental Monitoring Laboratories" (2). Calculation of the lab quality index (LQI) has been described previously (3) and the complete rating form used is presented elsewhere (4). Default items contained in the original documents' rating scheme and which were carried over to the modified form, were counted for each laboratory but not used directly to discount the validity of any laboratory's data. Furthermore, the absolute LQI cannot be directly assigned meaning as to the competence level of the laboratory. The original evaluation procedure set a score of 60 as the minimum passing score. This significance was maintained in the modified procedure used and consequently, scores below 60 clearly indicate reason to question the reliability. On the contrary, an LQI of 90 does not necessarily indicate a proportionally greater confidence in data reliability versus an LQI of 80.

The distribution of LQI values by EPA region is presented in Table 10. All but 3 laboratories achieved a passing score based on the criterion established. For the most part, the LQI values would imply that the data base is of acceptable analytical reliability.

Table 11 contains a summary of information that has been received from 239 treatment plants and entered into the computer. Data supplied were usually in the form of copies of laboratory records and contain entries for zero concentrations or less than a particular value. For some metals, the combination of less than or zero values was high. Notably, arsenic, cadmium and selenium had 42, 41 and 44 percent of the values reported in this fashion. Zinc and copper, on the other hand, were reported mostly as discrete values with only 2 and 8 percent of the values reported as zero or less than, respectively.

The range of values for each metal presented in Table 11 may reflect individual analytical anomalies at a given municipality but were the values supplied as verified by follow-up communication. Working with the data set requires some selective editing to evaluate if anomalous values are the result of infrequent or one-shot grab sampling, a single outlier in the data set, interference prone analysis and/or a low LQI.

DATA BASE EXAMINATION

Mean and Median Concentrations

For the case where no data editing is involved, the question arises as to how one handles inordinately high values or the zero and less than values. Furthermore, should equal weight be given to plants with fewer data points (even though the request procedure attempted to normalize this variation)? In looking at mean values and attempting to compute mass flow, concern must be directed at the "zero" or less than value. Is it really zero or just below the detection limit? The data of Tables 12 and 13 examine the difference between median and mean values, the latter computed in several different ways. Table 12 refers to "weighted values" defined as follows:

$$\text{Weighted Median} = \frac{\Sigma(\text{plant median x \# of observations for plant})}{\Sigma(\text{number of observations per plant})}$$

$$\text{Weighted Mean} = \frac{\Sigma(\text{plant mean x \# of observations for plant})}{\Sigma(\text{number of observations per plant})}$$

$$= \frac{\Sigma\text{individual values}}{\text{total \# of values}}$$

The former is actually a weighted mean of the median values while the latter is the overall mean of the composite data base. In both Tables 12 and 13, the mean values have been computed in four different ways: (1) Mean, LT=0 is computed by setting all less than values equal to zero and counting these and zero values in the denominator; (2) Mean, LT=value is computed by including zero values and setting all less than values equal to that value; (3) Mean, LT,0=Detection Limit is computed by setting all zero and less than values equal to the detection limit, either as reported or determined by the computer through selection of the lowest reported discrete value; (4) Mean, Discrete Values is computed by excluding all zero and less than values.

For the data of Table 12, the median values are consistently lower than all of the means (with the exception of arsenic) although in some cases little change is noted. Because of zero values, for some plants the individual medians are reported as zero and these values depress the mean of the medians relative to the mean values. Obviously, this is the result of more than 50% of the recorded values being zero. Setting of less than values equal to zero resulted in mean values less than the median values only for arsenic, beryllium, cobalt, antimony and selenium. For each of these elements, high percentages of the total observations were reported as less than or zero (42, 81, 27, 94 and 44%, respectively). For those metals for which a large number of observations were available (Cd, Cr, Co, Cu, Hg, Ni, Pb and Zn) the median values and the 3 mean values that considered zero and less than values in one manner or another were relatively close in magnitude (20 to 30%).

Comparison of Mean (LT=0) with Mean (LT=value) shows no significant change for chromium, copper, nickel, lead and zinc. For cadmium an 11% increase is seen and for mercury the increase is 40%. The large increase seen for arsenic and the anomalous behavior for the median versus the mean values is likely the result of unusual detection limits or less than values reported by one or more plants especially if a large fraction of the total data set comes from this source. The unweighted data smooth out this effect as will be seen below.

The mean of the discrete values reported is higher than the other values for silver, cadmium, chromium and nickel but by only 20 to 30%, not orders of magnitude. For other metals, the change is less (copper, mercury, lead and zinc).

Another way of examining the data is to assume equal reliability of the means and medians for each of the individual plant data sets. Table 13 presents the data in this manner, defined as follows:

$$\text{Unweighted median} = \frac{\Sigma\text{plant medians}}{\text{number of plants}}$$

$$\text{Unweighted mean} = \frac{\Sigma\text{plant means}}{\text{number of plants}}$$

Unweighted median values are slightly higher for silver, cobalt, manganese, nickel, lead and selenium, while the reverse occurred for arsenic, beryllium, cadmium, chromium, copper, mercury, antimony and zinc. A similar mix of plus and minus values was observed for the various unweighted means when compared to the weighted counterparts, but the differences are generally small except for mercury (unweighted values lower by roughly a factor of 10) and selenium (unweighted values higher by roughly a factor of 10). Interestingly, for the unweighted data, the change in values among the various computed means and even the median were much less than observed for the weighted values. Usually the median is less than the mean values and the Mean (LT=0) is less than the other mean values. In some cases, this difference is very small while for arsenic, beryllium, cobalt and antimony, larger changes are seen. Each of these elements has a large percentage of zero and less than values and/or is measured by relatively few treatment plants. Figure 1 contains a graphical presentation of the ranges, unweighted median and mean (LT=value) values for those heavy metals included in the priority pollutant list.

Distribution of Medians and Means

Cumulative distributions on the individual plant medians and means typically resulted in compression of most values at the axis due to dominance by 2 to 4 data points. Figures 2 and 3 illustrate this behavior for arsenic and cadmium, respectively, for individual plant median concentrations. Similar plots were obtained for each of the four means. Elimination of the top 4 values and replotting the remainder provides a better view of the data distribution as illustrated in Figures 4 and 5.

Examination of the highest 4 values for several elements for which substantial data were available indicated a pattern associated with those values. Table 14 summarizes this pattern for 9 elements. More commonly than not, the high values are associated with very few observations. Several plants are repeatedly represented for the 9 elements, usually those with limited observations; but in several instances, a substantial data base is represented. In these cases decimal errors in coding may be suspect or analytical interferences (example plant 298-1 analyzes for chromium by wet chemical procedures rather than atomic absorption spectrophotometry) or the plant has unusual contributions to its sewer. For the chromium case, plant 298-1 also reports a 40% industrial contribution by flow.

These factors may lead to the apparent differences in median concentrations in the ten EPA regions shown in Table 15. Copper and chromium values are highly elevated in Region I relative to other parts of the country. The two highest chromium and copper values are located in Region I which has only 15 plants represented in the total data base. Silver, arsenic and mercury also show wide variation among the regions.

Relationship Between Concentration and Descriptors

The relationship between the various descriptors selected and median (and the various mean) concentrations is illustrated for cadmium and zinc median concentrations versus percent of industrial flow in Figures 6 and 7, respectively. All such plots yielded similar scattergrams. Furthermore, examination for both parametric (Pearson) and nonparametric (Spearman and Kendall) associations did not yield large r values for any of the descriptors, including percent industrial flow. While these results may be contrary to expectations and results from specific studies on a smaller population size, they are not surprising when the entire data vase is used and emphasize the need to examine with judgment. First, several of the descriptors which would be expected to influence metals concentrations, work in opposition to each other. Secondly, variations in sample types, frequency, analytical method used and quality assurance program (if any) would lead to further noise in the data set. Additional and more sophisticated examination of the data is required and under study.

However, a significant number of plants reported low percent industrial flow contribution for seven of the metals measured. Table 16 indicates the distribution of plants in the 0 to 4% industrial category. Comparison of the respective median values for these two groups is presented in Table 17 from which it can be seen that in all cases the low percent industrial contribution values were lower. Application of the student T test to determine if these values are significantly different proved positive in all cases except for lead. Further comparisons of those plants reporting zero % industrial flow with those reporting 2% (1.5 - 2.5%) industrial flow did not show a significant difference for any of the metals except cadmium. The average zero% cadmium median was 0.0022 mg/l versus 0.0112 mg/l for the 2% industrial flow category ($T = -14.50$, $\alpha<0.0005$). Generally, similar values were obtained for comparison of the composite and 0-4% industrial flow means (discrete values).

In spite of the lack of correlation between percent industrial flow and metals concentration, the data base does allow sorting out of the background or base level contribution of several metals to POTWs from domestic sources. Upon closer examination and sorting of the data, particularly in conjunction with information on dominant industry types, better association between percent industry and metals concentrations might be expected.

SUMMARY

In summary, a composite picture of the data base on influent heavy metal concentrations to publicly owned treatment plants has been obtained. This picture is different from that obtained by preliminary telephone contact and initial correspondence with the municipalities. For the majority of municipalities responding, fairly detailed information has been assembled characterizing the data base in terms of plant type, frequency of sampling and analysis, metals analyzed, analytical method used, industrial contribution, extent of combined sewers and percent of infiltration and inflow. Over 90% of the cities were visited and their laboratories evaluated. The majority of these were found to be satisfactory or better, lending confidence to the reliability of the data base.

From the defined data base, a sampling of the individual plant data was obtained from 88% of the cities representing 239 individual treatment plants and nearly 80,000 data points have been computerized. The quantitative character of these data has been summarized, demonstrating wide variations in the range of values reported. Statistical associations between individual characteristics and the metals concentrations were not found for the composite data base, yet indications were presented that proper isolation of segments of the data with similar characteristics of sampling and analysis may disclose associations obscured by the total data base. Another example was shown for the low (0-4%) industrial segment of the data base versus the composite data. For several metals, the former category was significantly lower. Statistical analysis of the data base is continuing.

ACKNOWLEDGEMENT

The work presented in this paper has been supported under EPA Research Grant #R805606-01, MERL, Cincinnati. The able assistance of Douglas Allen and Lisa Sullivan, respectively graduate and undergraduate student in the Department of Civil Engineering, The University of Tennessee, is gratefully acknowledged.

REFERENCES

1. U.S. E.P.A., "Federal Guidelines - State and Local Pretreatment Programs," E.P.A. Reports - Nos. EPA-430/9-76-017a, b, and c, January 1977.
2. U.S. E.P.A., "Evaluation of Environmental Monitoring Laboratories," E.P.A. Report No. EPA-600/4-78-017, March 1978.
3. R. A. Minear, R. O. Ball, R. L. Church and D. Hines, "Data Base Location and Evaluation for Heavy Metals Discharge into Municipal Wastewater Systems," Proceedings of the 8th National Conference on Municipal Sludge Management, Information Transfer, Inc., Silver Spring, MD, pp. 48-54, 1979.
4. U.S. E.P.A., Final Report on Project #R805606-1, in press.

TYPING GUIDE SHEET

BEGIN FIRST LINE OF TEXT HERE

CENTER OF PAGE

TOP OF IMAGE AREA

DROPPED HEAD; BEGIN SECTIONS HERE

TABLE 1. NUMBER OF TREATMENT PLANTS SUPPLYING DATA BY EPA REGION

EPA Region	Number of Plants
I	15
II	24
III	32
IV	40
V	48
VI	17
VII	15
VIII	8
IX	37
X	3
	239

BEGIN LAST LINE OF TEXT

BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS

3/8''

EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD, BEGIN SECTIONS HERE

TABLE 2. DISTRIBUTION OF TREATMENT PLANT TYPES FOR INDIVIDUAL METAL MEASURES

	Number of Plants Treatment Plant Types					
Metal	Primary Treatment	Trickling Filter	Activated Sludge	Physical/ Chemical	Other	Unknown
Ag	9	11	28	3	4	21
Al	4	1	25	3	0	6
As	10	8	22	4	2	22
B	2	1	5	0	0	2
Ba	0	4	7	0	2	9
Be	2	0	2	1	0	4
Ca	0	1	2	0	0	0
Cd	22	21	104	5	7	39
Co	2	3	23	2	3	5
Cr	22	23	117	6	7	43
Cr(III)	0	0	3	0	1	0
Cr(VI)	1	1	5	1	1	5
Cu	25	25	123	6	7	41
Fe	10	14	80	5	5	28
Hg	17	11	50	4	3	29
K	0	0	1	0	0	0
Mg	0	1	2	0	0	1
Mn	5	10	38	3	3	20
Mo	0	0	3	2	0	4
Ni	21	23	104	6	7	34
Pb	21	18	100	5	6	41
Sb	0	0	7	2	0	2
Se	1	5	11	1	2	19
Si	0	0	13	0	0	7
Sr	0	0	1	0	0	0
Ti	0	0	1	0	0	1
Tl	0	0	2	0	0	1
V	2	0	2	0	0	2
Zn	24	24	119	6	7	40

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS

EPA-287 (Cin.)
(4-76)

TABLE 3. DISTRIBUTION OF SAMPLING FREQUENCY FOR INDIVIDUAL METALS MEASURED

	Number of Plants Frequency of Sampling and Analysis							
Metal	Daily	Weekly	Bi-Weekly	Monthly	Quarterly	Semi-Annual	Annual	Infr
Ag	6	10	2	36	11	6	1	4
Al	6	3	0	11	12	1	4	2
As	5	3	3	32	10	6	4	5
B	1	0	1	1	2	1	3	1
Ba	2	2	1	12	2	1	1	1
Be	2	1	0	2	3	0	1	0
Ca	1	0	1	0	0	1	0	0
Cd	39	51	7	47	25	8	6	15
Co	6	10	4	10	1	2	3	2
Cr	39	60	9	52	25	9	6	18
Cr(III)	0	0	1	0	0	3	0	0
Cr(VI)	4	1	2	4	0	3	0	0
Cu	46	62	10	46	27	11	7	18
Fe	26	42	2	37	14	5	8	8
Hg	15	22	4	32	16	8	4	13
K	1	0	0	0	0	0	0	0
Mg	3	0	0	0	0	0	0	1
Mn	10	12	2	31	11	4	5	4
Mo	0	0	0	3	3	0	2	1
Ni	36	54	5	50	26	9	5	10
Pb	31	49	6	47	25	11	5	17
Sb	2	2	0	3	1	1	1	1
Se	3	3	2	18	8	2	1	2
Si	0	11	0	4	2	0	2	1
Sr	1	0	0	0	0	0	0	0
Ti	0	0	0	0	2	0	0	0
Tl	0	0	0	1	2	0	0	0
V	2	0	0	3	1	0	0	0
Zn	43	60	7	49	26	11	6	18

EPA-287 (Cin.)
(4-76)

TABLE 4. DISTRIBUTION OF SAMPLE TYPES FOR INDIVIDUAL METALS MEASURED.

Metal	Number of Plants Sample Type 24 hr. Composite	Composite Unspecified	7 day Composite	30 day Composite	Grab	Unknown
Ag	47	2	0	2	1	24
Al	28	0	1	0	4	6
As	45	2	0	2	4	15
B	5	0	0	0	2	3
Ba	14	0	0	0	1	7
Be	7	0	1	0	0	1
Ca	2	1	0	0	0	0
Cd	123	7	3	13	10	42
Co	22	0	2	0	5	9
Cr	135	8	3	13	10	49
Cr(III)	3	0	0	0	0	1
Cr(VI)	7	0	0	0	0	7
Cu	145	7	3	14	10	48
Fe	94	7	2	11	4	24
Hg	70	2	1	13	5	23
K	1	0	0	0	0	0
Mg	2	1	0	0	1	0
Mn	50	2	3	2	3	19
Mo	7	0	0	0	1	1
Ni	122	8	3	14	6	42
Pb	117	8	3	14	7	42
Sb	7	0	0	0	1	3
Se	26	0	0	2	2	9
Si	3	0	0	11	1	5
Sr	1	0	0	0	0	0
Ti	1	0	0	0	0	1
Tl	2	0	0	0	0	0
V	6	0	0	0	0	0
Zn	139	8	3	14	8	48

EPA-287 (Cin.) (4-76)

TABLE 5. DISTRIBUTION OF ANALYSIS METHOD BY INDIVIDUAL METALS

	Number of Cities Method of Measurement				
Metal	Atomic Absorption	Wet Chemistry	Hach Kit	Other	Unknown
Ag	65	1	1	2	8
Al	35	0	0	3	1
As	55	7	0	0	6
B	6	1	0	1	2
Ba	18	3	0	0	1
Be	9	0	0	0	0
Ca	2	1	0	0	0
Cd	182	0	0	3	13
Co	20	9	4	2	3
Cr	188	6	5	4	15
Cr(III)	1	1	2	0	0
Cr(VI)	8	3	2	0	1
Cu	198	2	7	4	16
Fe	128	4	4	3	3
Hg	101	0	0	2	11
K	1	0	0	0	0
Mg	3	0	0	0	1
Mn	72	2	0	1	4
Mo	8	0	0	0	1
Ni	178	1	1	3	12
Pb	167	3	3	4	14
Sb	10	0	0	0	1
Se	34	4	0	0	1
Si	15	4	0	0	1
Sr	1	0	0	0	0
Ti	2	0	0	0	0
Tl	3	0	0	0	0
V	6	0	0	0	0
Zn	191	3	5	3	18

EPA-287 (Cin.)
(4-76)

TABLE 6. WHERE ANALYSES WERE CONDUCTED BY INDIVIDUAL METAL

Metal	Number of Plants	
	Outside Lab Analysis	Internal Analysis
Ag	15	61
Al	6	33
As	11	57
B	5	5
Ba	5	17
Be	4	5
Ca	1	2
Cd	20	178
Co	8	30
Cr	22	196
Cr(III)	2	2
Cr(VI)	2	12
Cu	23	204
Fe	13	129
Hg	14	100
K	0	1
Mg	2	2
Mn	10	69
Mo	4	5
Ni	21	174
Pb	20	171
Sb	2	9
Se	8	31
Si	2	18
Sr	0	1
Ti	1	1
Tl	1	2
V	0	6
Zn	22	198

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE

TABLE 7. DISTRIBUTION OF PERCENT OF PLANT FLOW ATTRIBUTABLE TO INDUSTRIAL CONTRIBUTION FOR INDIVIDUAL METALS MEASURED

	Number of Plants							
	Percent of Industrial Flow							
Metal	0-4	5-9	10-19	20-39	40-59	60-79	80-100	Unknown
Ag	8	10	35	11	7	2	2	1
Al	9	1	11	10	6	0	2	0
As	6	11	29	10	8	2	2	0
B	1	2	1	4	2	0	0	0
Ba	1	0	12	4	2	2	1	0
Be	1	0	3	2	2	0	1	0
Ca	0	0	2	1	0	0	0	0
Cd	29	25	64	44	25	6	3	2
Co	4	6	7	10	8	1	1	1
Cr	33	23	69	52	28	5	6	2
Cr(III)	0	2	2	0	0	0	0	0
Cr(VI)	0	3	6	3	2	0	0	0
Cu	34	27	73	51	28	6	6	2
Fe	21	16	43	41	16	2	2	1
Hg	18	16	50	15	11	2	2	0
K	0	0	0	1	0	0	0	0
Mg	0	0	2	1	1	0	0	0
Mn	12	8	28	21	7	1	1	1
Mo	0	1	4	3	0	0	1	0
Ni	24	21	69	42	26	6	4	3
Pb	28	23	71	37	22	5	3	2
Sb	1	0	3	5	0	0	2	0
Se	4	4	19	6	3	1	2	0
Si	2	3	11	3	0	0	1	0
Sr	0	0	0	1	0	0	0	0
Ti	0	0	0	2	0	0	0	0
Tl	0	0	0	2	0	0	1	0
V	0	1	2	1	1	0	1	0
Zn	33	25	74	48	26	7	5	2

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TABLE 8. DISTRIBUTION OF PERCENT COMBINED SEWERS FOR INDIVIDUAL METALS MEASURED.

Metal	Number of Plants Percent of Combined Sewers 0	1-30	31-60	61-100	Unknown
Ag	46	13	5	4	8
Al	28	5	5	1	0
As	39	13	4	2	10
B	6	3	1	0	0
Ba	13	4	4	1	0
Be	2	5	0	1	1
Ca	1	1	0	1	0
Cd	104	20	28	33	13
Co	21	8	6	3	0
Cr	117	22	32	34	13
Cr(III)	2	2	0	0	0
Cr(VI)	10	2	1	1	0
Cu	122	25	32	35	13
Fe	73	12	21	27	9
Hg	52	17	16	19	10
K	0	1	0	0	0
Mg	2	1	0	1	0
Mn	48	7	10	4	10
Mo	5	4	0	0	0
Ni	98	19	29	36	13
Pb	92	23	30	34	12
Sb	9	2	0	0	0
Se	21	6	2	1	9
Si	8	1	0	11	0
Sr	0	1	0	0	0
Ti	1	1	0	0	0
Tl	2	1	0	0	0
V	1	0	2	2	1
Zn	117	25	30	35	13

TABLE 9. DISTRIBUTION OF PERCENT INFILTRATION AND INFLOW FOR INDIVIDUAL METALS MEASURED.

Metal	Number of Plants Percent Infiltration/Inflow <25	 25-100	 >100	 Unknown
Ag	20	34	5	17
Al	10	24	2	3
As	16	33	6	13
B	3	4	2	1
Ba	7	10	2	3
Be	2	5	2	0
Ca	1	2	0	0
Cd	58	82	19	39
Co	9	16	3	10
Cr	68	86	25	39
Cr(III)	1	2	1	0
Cr(VI)	3	7	3	1
Cu	69	94	25	39
Fe	43	59	9	31
Hg	33	48	9	24
K	0	1	0	0
Mg	1	2	0	1
Mn	18	37	5	19
Mo	1	6	0	2
Ni	57	86	18	34
Pb	55	82	16	38
Sb	2	7	0	2
Se	4	22	3	10
Si	12	6	0	2
Sr	0	1	0	0
Ti	1	1	0	0
Tl	1	1	0	1
V	0	5	1	0
Zn	65	92	23	40

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

TABLE 10. LAB QUALITY INDEX DISTRIBUTION

	Number of Cities with a Given LQI										
	EPA Region										
LQI	1	2	3	4	5	6	7	8	9	10	Total
48		1									1
53	1										1
59		1									1
				Minimum passing score							
60				1		1				1	3
61		1									1
63				1	1						2
64									1		1
65				1	3						4
66				1			1				2
67					1			1			2
68				3							3
69				2	1		1				4
70			1			7					8
71	1				1	2					4
72			1		2						3
73							2				2
74				1							1
75			3				1				4
76			1	5							6
77		1			3						4
78	1			2					1		4
79	5				1						6
80					2			2	2		6
81			1	3							4
83					1				4		5
84					2	5			1		8
85					1		1				2
86					3	1					4
87					4						4
88		1					3		3		7
89					2				1		3
91					1		2		8		11
93					2				1		3
94					1						1
96			9		6						15
∑	8	5	16	20	38	16	11	3	22	1	140

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

TABLE 11. SUMMARY OF HEAVY METALS DATA BASE FROM 238 WASTEWATER TREATMENT PLANT INFLUENTS.

Metal	Number of Observations Observations	Number <a value	Number Zero	Concentration, mg/l Maximum*	Minimum#
Ag	1,696	186	196	0.900	0.0015
Al	857	6	7	186.0	0.0017
As	1,140	222	251	1.90	0.0005
B	101	83	1	20.0	0.123
Ba	441	39	109	13.5	0.010
Be	171	103	36	0.090	0.001
Cd	8,937	1,214	2,455	2.14	0.0002
Co	323	77	17	0.900	0.0011
Cr	11,362	693	840	83.3	0.0008
Cu	12,351	243	686	36.5	0.0001
Fe	8,558	158	73	999.0	0.006
Hg	2,698	357	176	3.00	0.0001
Mn	2,302	8	26	13.2	0.008
Mo	22	17	0	0.874	0.0011
Ni	9,461	938	1,029	111.4	0.002
Pb	7,521	540	900	11.6	0.001
Sb	155	88	57	2.10	0.0003
Se	592	97	156	10.0	0.0002
Sn	6	3	0	13.3	0.010
Sr	85	8	0	0.45	0.025
Ti	4	0	0	2.00	0.14
V	125	95	1	3.10	0.50
Zn	11,341	116	96	28.7	0.0001
Total	80,241	5,410	7,214		

*individual values for the entire data set

#smallest discrete value reported for the entire data set

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS

EPA-287 (Cin.)
(4-76)

TABLE 12. COMPARISON OF MEDIAN AND MEAN VALUES (WEIGHTED) FOR THE ENTIRE DATA BASE.

Metal	#Observ	#Plants	Median*	Mean* LT=0	Mean* LT=Value	Mean* LT,0=Det.Lim.	Mean* Discrete Values
Ag	1,696	76	.017	.024	.026	.026	.032
Al	854	39	2.41	3.39	3.39	3.39	3.44
As	1,140	68	.085	.012	.069	.069	.021
Be	171	9	.0091	.0040	.0097	.0098	.0216
Cd	8,937	198	.024	.027	.030	.030	.046
Co	323	38	.053	.050	.066	.066	.070
Cr	11,362	218	.40	.45	.45	.45	.52
Cu	12,351	227	.42	.46	.46	.46	.49
Fe	8,558	142	3.18	5.13	5.13	5.13	5.27
Hg	2,698	114	.063	.11	.14	.14	.14
Mn	2,302	79	.16	.17	.17	.17	.18
Ni	9,461	195	.23	.31	.32	.32	.39
Pb	7,521	191	.12	.15	.16	.16	.18
Sb	155	11	.43	.24	.37	.37	.37
Se	592	39	.041	.038	.047	.047	.066
Zn	11,341	220	.52	.63	.63	.63	.64

*Values reported as mg/1.

EPA-287 (Cin.)
(4-76)

TABLE 13. COMPARISON OF MEAN AND MEDIAN VALUES* (UNWEIGHTED) FOR THE ENTIRE DATA BASE.

Metal	Median	Mean LT=0	Mean LT=Value	Mean LT,0=Det.Lim.	Mean Discrete Values
Ag	.021	.028	.030	.030	.028
Al	2.98	3.70	3.72	3.72	3.70
As	.048	.035	.050	.050	.035
Be	.0069	.0025	.0072	.0076	.0025
Cd	.024	.024	.029	.030	.024
Co	.056	.035	.066	.067	.035
Cr	.39	.44	.45	.45	.44
Cu	.35	.38	.39	.39	.39
Fe	3.44	4.79	4.79	4.80	4.79
Hg	.011	.013	.019	.019	.013
Mn	.35	.37	.37	.37	.37
Ni	.26	.31	.32	.32	.31
Pb	.14	.16	.19	.19	.16
Sb	.22	.09	.22	.22	.09
Se	.31	.28	.30	.30	.28
Zn	.51	.61	.61	.61	.61

*Values reported as mg/l.

TABLE 14. LISTING HIGHEST 4 MEDIAN AND MEAN (DISCRETE VALUES) FOR NINE ELEMENTS.

	Median Values			Discrete Value Mean		
Element	Plant #	Median mg/1	# Observ	Plant #	Mean mg/1	# Observ
Arsenic	456-1	1.56	1	456-1	1.56	1
	432-1	1.00	88 (75<)*	877-4	.48	7 (3<)*
	635-1	0.07	8	877-3	.11	8 (5<)
	4 Plants	0.005		641-1	.065	17
Cadmium	456-1	.85	1	456-1	.85	1
	577-1	.30	32 (28<)	514-1	.19	360
	359-1	.20	3	359-1	.17	3
	514-1	.18	360	295-1	.13	3 (2<)
Chromium	298-1	32.6#	31	298-1	33.3#	31
	715-5	4.9	6	715-1	4.8	12
	584-1	3.1	329	715-5	4.1	6
	643-1	2.8	6	715-3	2.9	13
Copper	58-1	26.0	1	58-1	26.0	1
	179-2	11.5	232	179-2	11.2	232
	2234-1	1.7	29	2234-1	2.4	29
	519-1	1.03	82	519-1	1.3	82
Mercury	546-1	0.60	301	546-1	1.01	301
	617-1	0.50	4 (4<)	877-1	0.23	10 (1<)
	359-1	0.028	3	359-1	0.058	3
	514-1	0.010	2	132-1	0.048	79 (40=0)
Nickel	2234-1	11.3	29	2234-1	16.3	29
	359-1	9.5	3	359-1	8.6	3
	58-1	2.4	1	58-1	2.4	1
	456-1	1.5	1	215-1	1.5	234
Lead	295-3	8.5	1	295-3	8.5	1
	295-9	2.7	4	295-9	2.7	4
	491-1	1.1	3	321-1	1.2	139 (134=0)
	359-1	0.72	3	491-1	1.0	3
Selenium	295-3	10.0	1	295-3	10.0	1
	617-1	1.0	6 (6<)	15-2	0.34	3
	15-1	.37	3	15-1	0.19	3
	15-2	.19	3	2234-1	0.15	34
Zinc	58-1	10.3	1	58-1	10.3	1
	2234-1	3.14	29	2234-1	4.88	29
	530-1	3.12	96	530-1	3.99	96
	456-1	3.10	1	456-1	3.10	1

---

*(<) indicates number of total values reported as less than a particular value

#wet chemical analysis. Others atomic absorption.

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
DROPPED HEAD: BEGIN SECTIONS HERE
CENTER OF PAGE
TOP OF IMAGE AREA
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA. OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TABLE 15. MEDIAN CONCENTRATION (UNWEIGHTED) BY EPA REGION

Region	Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
I	0.025	0.0080	0.029	3.40	2.45	0.0023	0.52	0.29	1.19
II	0.038	0.0098	0.0092	0.093	0.28	0.0010	0.54	0.075	0.52
III	0.0035	0.0017	0.0070	0.12	0.16	0.0008	0.11	0.23	0.44
IV	0.059	0.21	0.051	0.092	0.081	0.0031	0.42	0.092	0.38
V	0.0067	0.010	0.038	0.37	0.47	0.031	0.18	0.15	0.66
VI	0.0051	0.0083	0.012	0.064	0.10	0.0007	0.065	0.056	0.18
VII	0.022	0.027	0.025	0.34	0.14	0.064	0.14	0.15	0.42
VIII	0.0010	0.0010	0.013	0.081	0.19	0.0044	0.22	0.089	0.36
IX	0.020	0.0058	0.018	0.18	0.25	0.0010	0.15	0.12	0.50
X	-	-	0.014	0.10	0.21	0.0013	0.080	0.13	0.65
Composite National	0.021	0.048	0.024	0.39	0.35	0.011	0.26	0.14	0.51
$\frac{\text{Maximum}}{\text{Minimum}}$	59	210	7.3	53	30	91	8.3	3.9	6.6

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

TABLE 16. BREAKDOWN OF PLANTS REPORTING IN THE RANGE OF 0-4% INDUSTRIAL FLOW CONTRIBUTION.

Metal	Number of Plants Reporting Indicated Industrial Flow Contributions				
	0%	1%	2%	3%	4%
Cd	20	4	11	0	0
Cr	21	4	13	0	1
Cu	22	4	13	0	1
Hg	12	2	8	0	0
Ni	10	2	12	0	0
Pb	19	3	12	0	0
Zn	22	4	13	0	0

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
EPA-287 (Cin.)
(4-76)

TABLE 17. COMPARISON BETWEEN COMPOSITE DATA BASE VALUES AND THOSE OBTAINED FROM PLANTS WITH 0-4% INDUSTRIAL FLOW CONTRIBUTION.

Metal	Composite Median	0-4% Median	Composite Median / 0-4% Median	T*	α	Significant Difference
Cd	.023	.0064	3.6	- 8.96	<<0.005	Yes
Cr	.37	.030	12.3	- 58.1	<<0.005	Yes
Cu	.34	.097	3.5	- 17.2	<<0.005	Yes
Hg	.010	.0005	20	-104	<<0.005	Yes
Ni	.26	.049	5.3	- 27.3	<<0.005	Yes
Pb	.17	.11	1.5	- 0.741	>>0.10	No
Zn	.50	.22	2.3	- 8.28	<<0.005	Yes

*Student T test value.

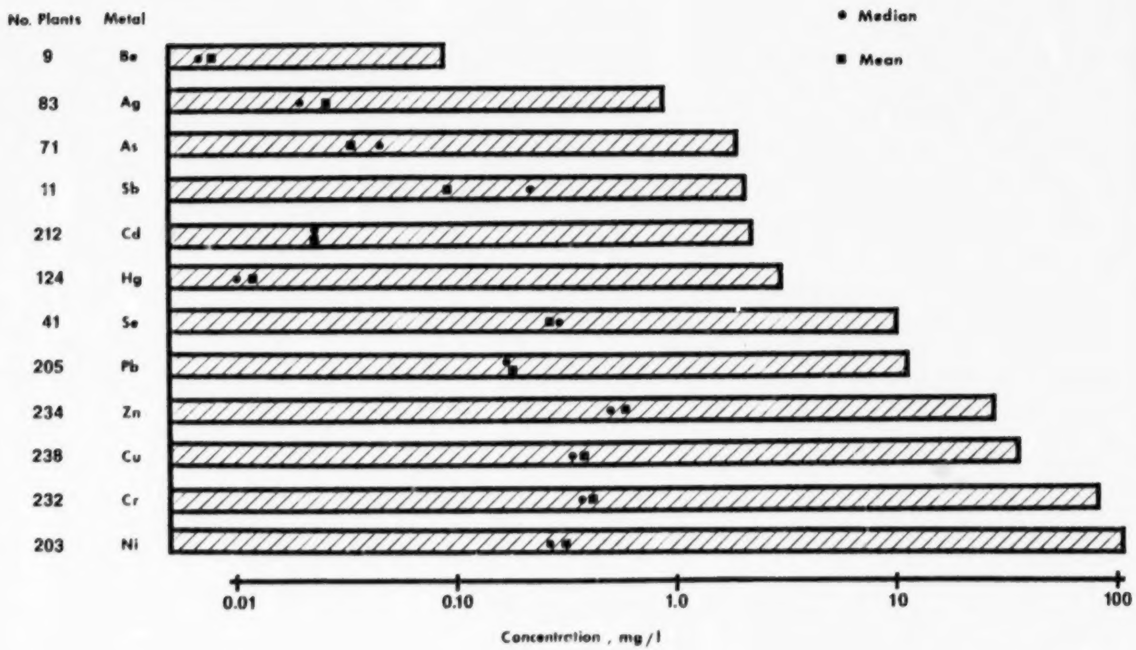


Figure 1. Range of individual concentrations reported and unweight median and mean (LT=value) concentrations for metals on the priority pollutant list.

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE

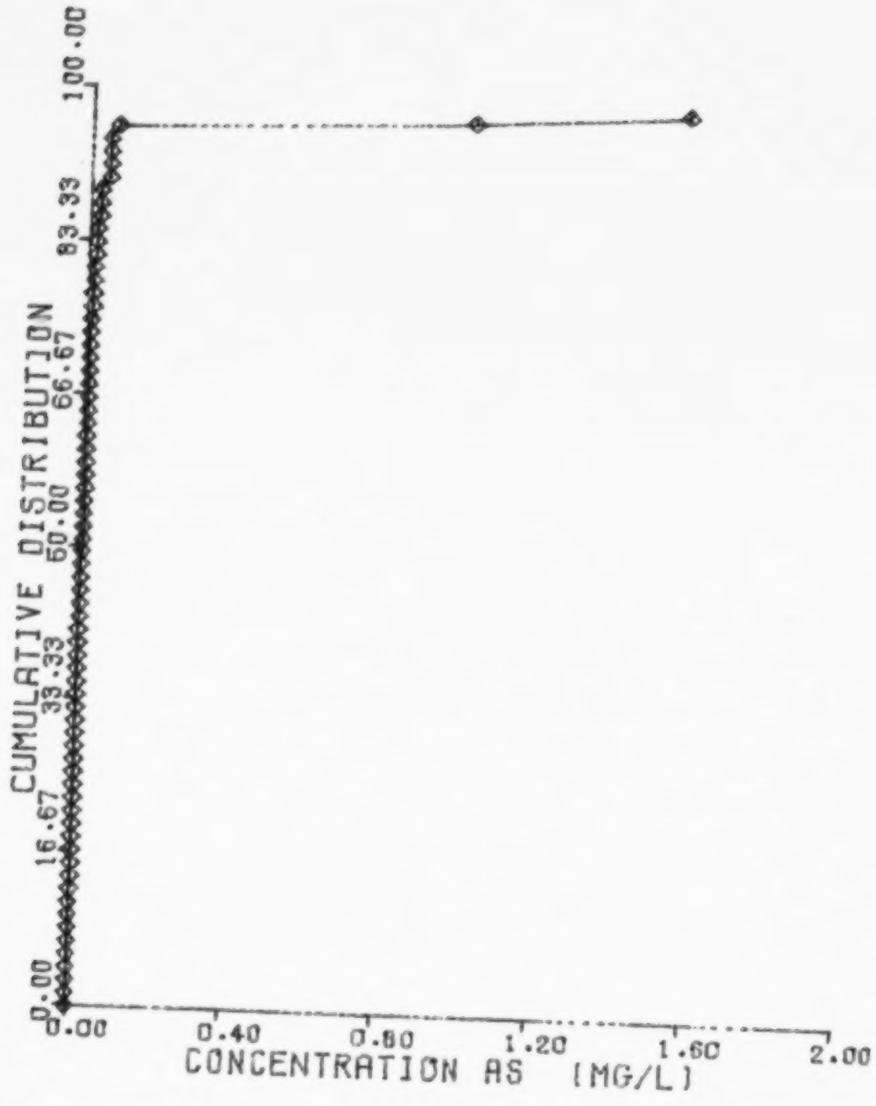


Figure 2. Cumulative distribution of individual plant median arsenic concentrations.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS

EPA 287 (Cin)
(4-76)
PAGE NUMBER

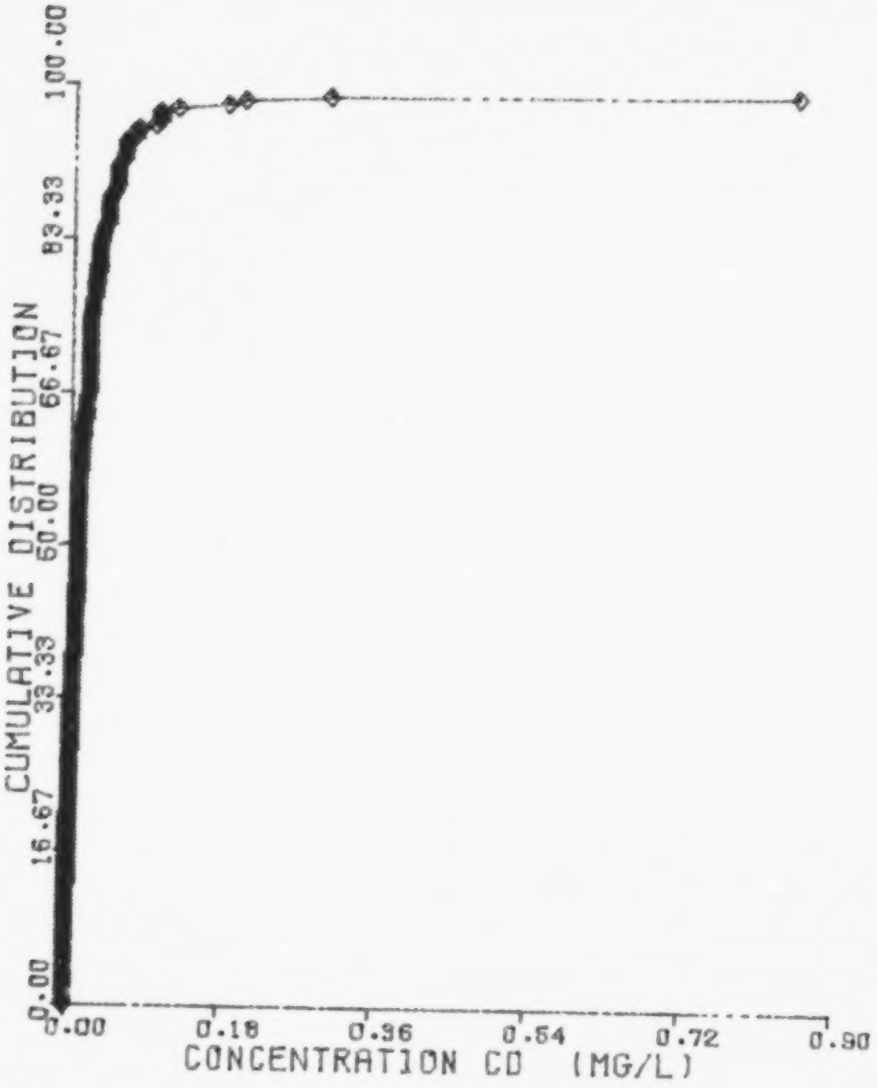


Figure 3. Cumulative distribution of individual plant median cadmium concentrations.

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE

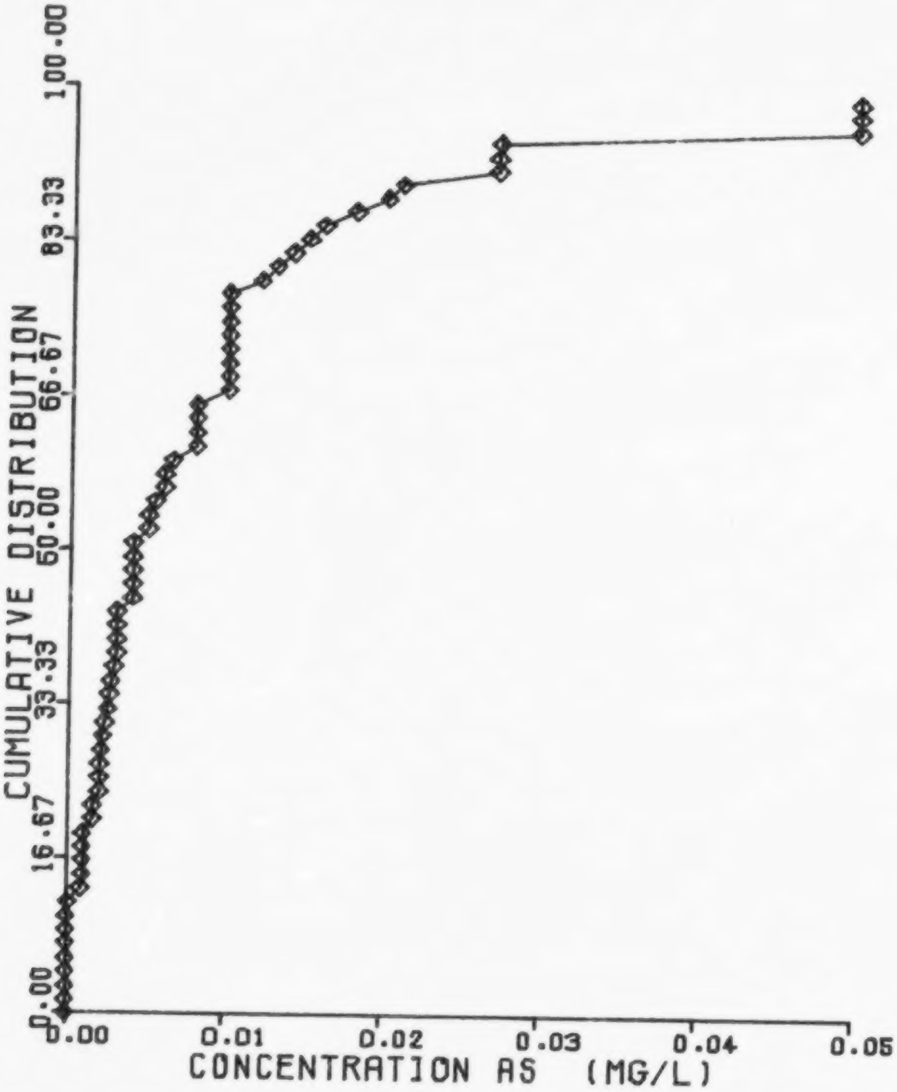


Figure 4. Cumulative distribution of individual plant median arsenic concentrations after deletion of the four highest values.

BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
PAGE NUMBER

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE

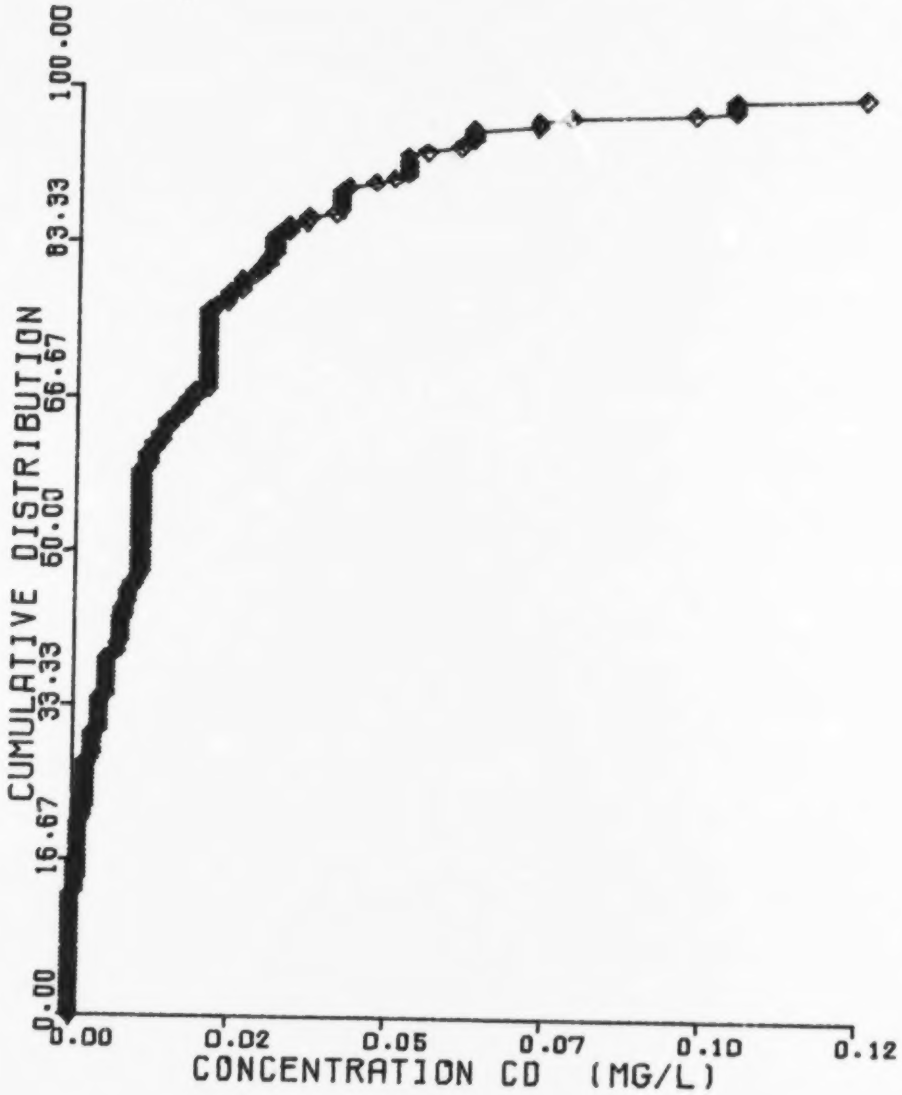


Figure 5. Cumulative distribution of individual plant median cadmium concentrations after deletion of the four highest values.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE

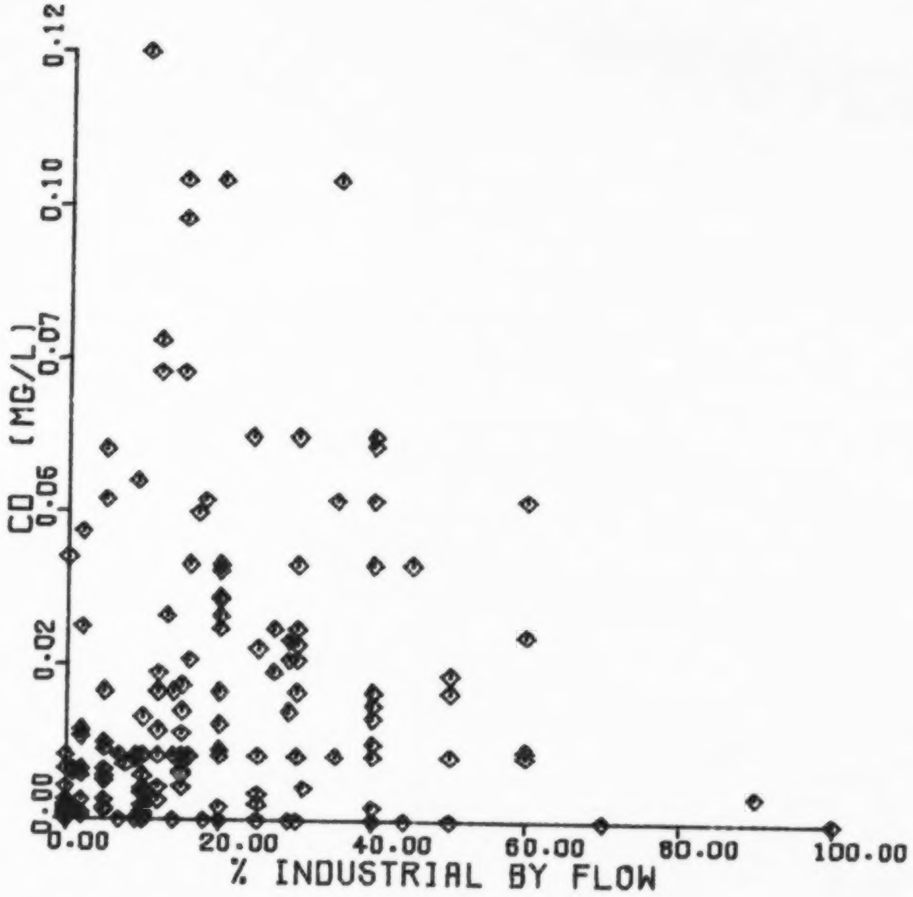


Figure 6. Distribution of individual plant median cadmium concentrations as a function of industrial contribution to total plant flow.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE

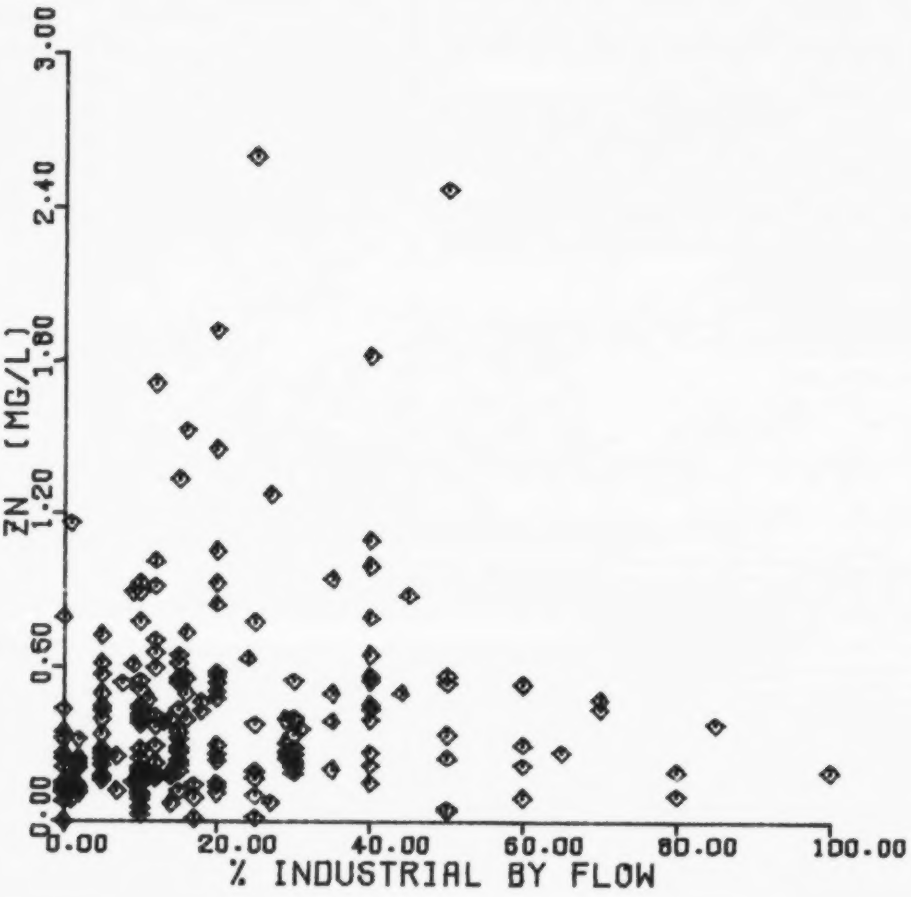


Figure 7. Distribution of individual plant median zinc concentrations as a function of individual contribution to total plant flow.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
PAGE NUMBER

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

PB83-142455

SOURCES AND FLOW OF HEAVY METALS AND CYANIDE IN THE KOKOMO MUNICIPAL TREATMENT SYSTEM

K. J. Yost, T. G. Adams and R. F. Wukasch
Purdue University
West Lafayette, Indiana

INTRODUCTION

The objective of this study was to establish a protocol to assist communities in identifying, quantifying, and formulating regulatory policies for reduction of heavy metal and cyanide discharges to publicly owned treatment works (POTW) to the point that land disposal of sludge is feasible.

Establishment of a routine to obtain representative samples from likely metals and cyanide sources (nonpoint, point, and street surface) was of primary importance. This involved determining sampling station locations and sampling frequencies for point source and trunkline monitoring. The final concern was establishment of pretreatment strategy alternatives to reduce metal and cyanide inputs to the sewer network of a representative city to levels consistent with land disposal of digestor sludge. The control strategy evolved during the study may be implemented by imposing, or modifying existing city ordinances which limit concentrations of trace metals and cyanide in industrial waste discharged to the sewer network.

The prototype community selected for this study was Kokomo, Indiana. It is a medium-sized city (42,000) with (from the sampling and analysis point of view) a manageably sized combined sanitary and storm sewer treatment network which serves well-defined residential areas and a diverse industrial community. The industrial and commercial makeup of Kokomo includes such industrial categories as electroplating, metal fabricating, automotive manufacture, chemical processing, and food processing.

Kokomo was chosen for the study for several reasons. Sewer system networks of large cities are so complex that they virtually defy definitive flow analysis and/or quantitative source identification. Samller communities tend to have atypical residential-industrial flow compositions. Kokomo provided a wastewater flow mixture typical of an industrialized city (i.e., one that has neither an over-abundance nor a paucity of domestic or industrial sources discharging to the sewer network).

The treatment facility which serves the city of Kokomo is a newly renovated 30 MGD (million gallons per day) activated sludge multimedia gravity

BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
BEGIN LAST LINE OF TEXT
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

filter plant. The sewer system is composed of six major trunklines serving the city and surrounding areas. Three of these trunklines are classified as purely residential, while the other three carry a combination of residential, commercial, and industrial wastewater. The city layout is such that the northern section (older part) is served by a combination storm and sanitary collection network, with overflows going to Wildcat Creek. The southern section of the city (new part) is served by a separate storm and sanitary collection system. Storm water is discharged to the Wildcat and Kokomo creeks.

SAMPLING PROTOCOL

Trunkline sampling was conducted from April, 1978, to June, 1979, at twelve locations in the Kokomo sewer network (Figure 1). These locations were chosen to characterize metal and cyanide input to the treatment plant. Automatic sequential samplers (ISCO-1680)[1] and continuous flow recorders (Stevens F-68)[2] were used at each sampling location to measure metal and cyanide mass flow rates.

Samples were obtained for each trunkline at 2-hour intervals for three 24-hour periods. Sampling was conducted on a Monday through Thursday schedule, when feasible, to avoid any unusual fluctuations in flow or metal and cyanide discharge due to variations in industrial work schedules or increased residential activity during the weekend. Flow rates were determined using a combination of continuous flow recorders and sharp-crested weirs.

One of the most critical steps in any sewer monitoring program is the selection of appropriate sampling site locations. An appropriate sampling site is one which provides: (1) easy accessibility to and from the site, (2) sufficient space to construct sampling and flow recording equipment, (3) a suitable location with little or no slope and a straight section of the sewer to obtain accurate sampling and flow data, and (4) a critical point in the collection system for quantification of flow and pollutants. Site selection during the study was difficult. Most problems involved insufficient space for sampling and flow recording equipment and/or sloped sewers with no straight sections in which proper weir construction was possible.

Metal samples were collected in 500 ml acid-washed polyethylene bottles pre-preserved with 2 ml of 1:1 redistilled nitric acid. Samples were analyzed with a Perkin-Elmer Model 5000 atomic absorption spectrophotometer. Cyanide analyses were conducted as specified in *Methods for Chemical Analysis of Water and Wastes*, 1974. Samples were collected in 500 ml acid-washed polyethylene bottles to which 2 ml of 10 N NaOH and 10 ml of 3 percent acid were added prior to collection. The sequential samplers used to collect cyanide wastes were packed with ice to maintain an approximately 4° C environment prior to refrigeration. Samples were in general analyzed within twenty-four hours of collection.

POINT SOURCE TESTING

The quantification of metal and cyanide input from specific industries to the Kokomo sewage treatment plant yielded a data base which operators of other publicly owned treatment works (POTW) may utilize to estimate metal and

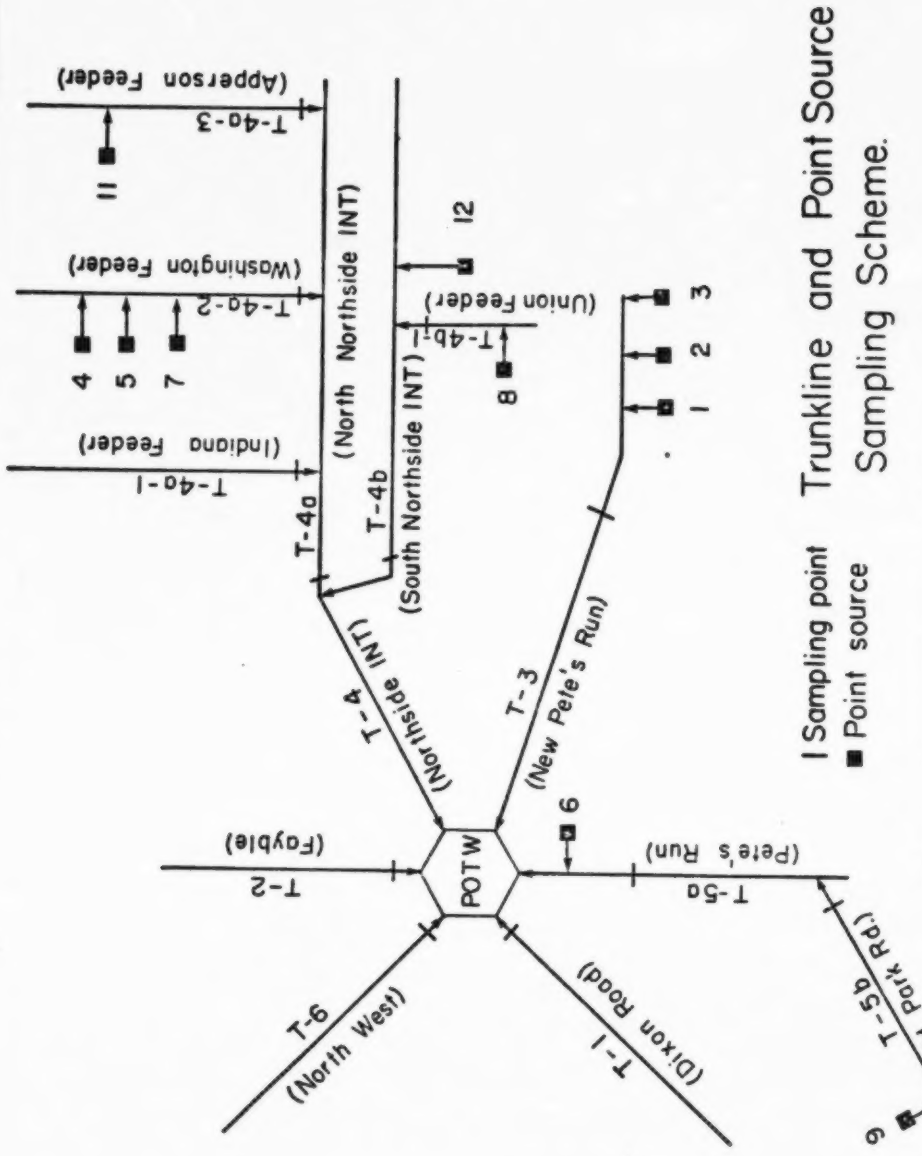

Trunkline and Point Source Sampling Scheme.
I Sampling point
■ Point source
POTW
T-6
(North West)
T-1
(Dixon Road)
T-2
(Fayble)
T-4
(Northside INT)
T-3
(New Pete's Run)
T-5a
(Pete's Run)
T-5b
(Old Park Rd.)
T-4a
(North Northside INT)
T-4b
(South Northside INT)
T-4a-1
(Indiana Feeder)
T-4a-2
(Washington Feeder)
T-4a-3
(Apperson Feeder)
T-4b-1
(Union Feeder)
1
2
3
4
5
6
7
8
9
10
11
12

Figure 1. A simplified drawing of the Kokomo sewer system.

cyanide input to their particular collection systems. Where treatment was practiced, sampling raw and treated wastes of point sources discharging to the Kokomo system may provide information on degrees of pollutant removal which are feasible for the types of industries surveyed here. This information may in turn be useful for determining technologically feasible discharge limits for these industrial categories which reduce heavy metal and cyanide levels in sludge to the point that land disposal of sludge is feasible.

Twelve known point sources of heavy metals and cyanide identified by Standard Industrial Classifications (SIC) were sampled in this study over a 3-month period in 1979 (see Figure 1). Flow data from these point sources were obtained from flow meters and/or city water meters available at each one. In one case, a pair of V-notch weirs with a recording depth-of-flow indicator (Stevens flow recorder and float) was employed to measure flow above and below the point of discharge.

Sampling at each source was conducted at 2-hour intervals for 24 hours over a consecutive three-day period. Metal and cyanide samples were collected using an automatic sequential sampler (ISCO). The treatment and analysis of these samples are described elsewhere in this report.

POINT SOURCES

Point Source 1 is a major manufacturer of automatic transmissions and aluminum die castings for the automotive industry. Over 9,000 transmissions are produced daily.

Effluent wastes from the transmission plant and die cast plant are collected in a common receiving pit for solids settling. Overflow from the receiving pits is transferred to batch tanks. Underflow (solids) is transported to an approved landfill for disposal. Treated effluent from the batch tank is discharged to the Kokomo sanitation network. The final effluent from Point Source 1 is presented in Table 1.

Point Source 2 conducts circuit board plating operations as well as some soldering and assembling of radio components. The treatment facilities at Point Source 2 are primarily intended to treat electroplating effluents. All process waste from the circuit board plating operations goes to batch treatment facilities where metal-bearing and dilute cyanide-bearing wastes are treated separately. Metals waste treatment consists of pH adjustment and precipitation, primarily as hydroxides. A pH of 9.0 is maintained in the clarifier. Cyanide waste treatment consists of two-phase destruction of cyanide to carbon dioxide and nitrogen gases. This process utilizes sodium hydroxide to raise the pH to 10.5, while adding chlorine gas in the recirculation line. The pH is reduced to 8.5 and chlorine added until cyanide destruction is complete. After treatment, effluent from the metal waste and cyanide waste tanks is pumped into a waste blending tank (30,000 gal). The effluent of Point Source 2 is presented in Table 2.

Point Source 3 manufactures various radios and radio parts, as well as semiconductor components. Other products include digital controls, silicon rectifiers, and microelectronic voltage regulators. Some plating of radio

EPA-287 (Cin.)
(4-78)

TABLE 1. DAILY DISCHARGES OF METAL AND CYANIDE FROM POINT SOURCE 1 TO NEW PETE'S RUN (T-3) TRUNKLINE.

	Effluent (mgd)	Pounds Per Day						
		Cd	Cr	Ni	Pb	Zn	Cu	CN^-
Day 1	0.496	0.006	0.034	0.28	0.14	3.02	0.20	<0.42
Day 2	0.379	0.004	0.018	0.16	0.088	1.32	0.16	<0.33
Day 3	0.446	0.004	0.048	0.21	0.080	1.40	0.44	<0.38
Mean	0.440	0.005	0.033	0.22	0.10	1.91	0.27	<0.38
S.D.	0.059	0.001	0.015	0.06	0.03	0.96	0.15	0.05

TABLE 2. DAILY DISCHARGES OF METAL AND CYANIDE FROM POINT SOURCE 2 TO NEW PETE'S RUN (T-3) TRUNKLINE.

	Effluent (mgd)	Pounds Per Day						
		Cd	Cr	Ni	Pb	Zn	Cu	CN^-
Day 1	0.720	0.19	0.11	0.19	<0.078	1.15	6.74	<0.99
Day 2	0.270	0.044	0.032	0.034	<0.027	0.26	2.16	<0.25
Day 3	0.324	0.054	0.034	0.034	<0.027	0.38	2.54	<0.28
Mean	0.438	0.096	0.058	0.086	0.020	0.60	3.81	<0.51
S.D.	0.246	0.082	0.045	0.090	0.029	0.49	2.54	0.42

parts is also conducted at this location. The wastewater treatment facilities installed at Point Source 3 are primarily intended to treat electronic semiconductor manufacturing and electroplating effluents. Treatment of metal waste consists of pH adjustment and precipitation of heavy metals as hydroxides. Chemical reactants for pH control are lime (cadmium hydroxide) with sodium hydroxide as an emergency backup to raise the pH and sulfuric acid to lower the pH. A pH of 9.0 is maintained in the clarifiers. There are three metal waste treatment tanks, holding 1.4 million gallons each. Cyanide waste treatment consists of a two-phase destruction of cyanide to carbon dioxide and nitrogen gas. This is accomplished by the addition of lime to raise the pH to 10.5, while adding chlorine gas in the recirculation line. Sodium hydroxide is used as a backup for the lime. The pH is reduced to 8.5 and chlorine is added until cyanide destruction is complete. There are three cyanide waste treatment tanks, each holding 0.19 million gallons. The final effluent characteristics are given in Table 3.

Point Source 4 manufactures major products for the automotive, construction, and agricultural industries. Treatment facilities include a 600-gallon chromium reduction tank equipped with pH controls, sulfuric acid, and sodium bisulfite feed equipment and mixer, two 9,000-gallon batch neutralization tanks equipped with pH controls, and a 50-gallon per minute continuous belt vacuum filtration unit. These values represent a metal removal efficiency of >99 percent for total chrome and >98 percent for zinc. Point Source 4 discharge to the Kokomo sanitary sewage system is presented in Table 4. At the time of sampling, the chrome pretreatment unit was constructed but not in operation.

Point Source 5 specializes in plating various manufactured products. It provides services for both rack and barrel, plating and finishes including cadmium, hard chromium, zinc, copper, nickel, silver, and tin plating. The copper, zinc, cadmium, and silver plating lines utilize cyanide solutions. No treatment of metal and cyanide wastewater is presently practiced. Effluents from plating operations are discharged directly to the Kokomo sewer network, and acid and alkali baths are dumped to the city sewer once every two weeks. The effluent from Point Source 5 is presented in Table 5.

Point Source 6 is a manufacturer of high and low carbon steel wire for industrial and commercial use. Its products also include nails, various wire products, fencing, and other galvanized material for farm, industrial, and domestic use. Wastes with pollution potential emanate from (1) steel melting, (2) primary rolling, (3) secondary rolling, (4) pickling, and (5) coating facilities. The contaminants include oils, solids, chemicals, metals, and acids. The waste treatment system of Point Source 6 includes both nonchemical (mechanical) and chemical treatment for removing contaminants from the mill cooling and process water. Metal and cyanide concentrations in plant effluent are shown in Table 6.

The major product of Point Source 7 is "hot dipped" galvanized woven chainlink fencing. No special treatment facilities exist at this location except the batch type neutralization of etching acid. Discharge wastewater consists of rinse from the alkaline process, quench water from the chainlink

TABLE 3. DAILY DISCHARGE OF METAL AND CYANIDE FROM POINT SOURCE 3 TO NEW PETE'S RUN (T-3) TRUNKLINE.

	Effluent (mgd)	Pounds Per Day						
		Cd	Cr	Ni	Pb	Zn	Cu	CN⁻
Day 1	1.549	0.71	0.13	0.59	<0.13	17.98	3.49	<1.33
Day 2	1.539	0.65	0.12	0.65	<0.13	44.12	5.01	2.19
Day 3	1.944	0.75	0.15	1.01	<0.47	30.60	5.04	≤4.46
Mean	1.677	0.70	0.13	0.75	<0.28	30.90	4.51	≤3.55
S.D.	0.231	0.05	0.02	0.23	0.20	13.11	0.89	1.67

TABLE 4. DAILY DISCHARGES OF METAL AND CYANIDE FROM POINT SOURCE 4 TO WASHINGTON FEEDER (T-4a-2) AND SUBSEQUENTLY TO THE NORTH NORTHSIDE INTERCEPTOR (T-4a).

	Effluent (mgd)	Pounds Per Day						
		Cd	Cr	Ni	Pb	Zn	Cu	CN⁻
Day 1	0.095	<0.002	≤7.75	≤0.033	≤0.035	20.82	0.17	<0.079
Day 2	0.092	≤0.002	6.24	≤0.026	0.054	32.02	0.094	<0.077
Day 3	0.093	≤0.002	11.97	≤0.008	0.041	1.17	0.096	<0.078
Mean	0.093	<0.002	<8.65	≤0.023	≤0.043	18.00	0.12	<0.078
S.D.	0.015	0.000	2.97	0.013	0.009	15.63	0.04	0.001

TABLE 5. DAILY DISCHARGES OF METAL AND CYANIDE FROM POINT SOURCE 5 TO THE WASHINGTON FEEDER (T-4a-2) AND THE NORTH NORTHSIDE INTERCEPTOR (T-4a).

	Effluent (mgd)	Pounds Per Day						
		Cd	Cr	Ni	Pb	Zn	Cu	CN⁻
Day 1	0.235	0.41	39.12	6.21	0.067	1.10	0.67	≤0.45
Day 2	0.213	0.36	79.93	3.45	0.067	1.48	0.61	0.43
Day 3	0.264	0.94	130.36	4.69	0.51	3.77	1.63	3.72
Mean	0.237	0.57	83.23	4.78	0.21	2.12	0.97	≤1.53
S.D.	0.026	0.32	45.70	1.38	0.26	1.44	0.57	1.89

TABLE 6. DAILY DISCHARGES OF METAL AND CYANIDE FROM POINT SOURCE 6 TO PETE'S RUN INTERCEPTOR (T-5a).

	Effluent (mgd)	Pounds Per Day						
		Cd	Cr	Ni	Pb	Zn	Cu	CN⁻
Day 1	0.384	0.010	0.14	0.41	0.97	1104.90	0.45	<0.76
Day 2	0.384	≤0.004	0.022	0.19	0.16	210.40	0.21	<0.32
Day 3	0.384	≤0.008	0.055	0.27	0.27	239.52	0.51	<0.33
Mean	0.384	≤0.007	0.072	0.29	0.47	518.27	0.39	<0.47
S.D.	0.000	0.003	0.061	0.11	0.44	508.24	0.16	0.25

fencing process, and acid drippings from the etching process. Final effluent concentrations are presented in Table 7.

Point Source 8 manufactures architectural aluminum entrances for all types of commercial buildings. It also manufactures extruded aluminum storefront and curtain wall systems for the commercial construction market. The prime functions of this plant include aluminum extrusion, anodizing, and fabrication. Wastewater discharged to the Kokomo sewage network consists of de-ionizer regenerant solution, water softener backwash, boiler blowdown, and anodizing rinse waters. The plant has a two-stage neutralization and equalization treatment facility. Wastewater from the de-ionizers and ion exchange regenerators is consolidated prior to discharge into an equalization tank (10,000 gal). Sulfuric acid anodizing solution is then pumped into the equalization tank. Anodizing rinse water and effluent from the equalization tank are discharged into a primary neutralization tank (17,900 gal) and then into a secondary neutralization tank (4,700 gal). Chemical feed for both neutralization tanks consists of sodium hydroxide and sulfuric acid. Effluent from the secondary neutralization is pumped directly into the Kokomo sanitary sewer. The water softener backwash and the boiler blowdown are not treated. The final effluent of Point Source 8 is presented in Table 8.

Point Source 9 manufactures high performance nickel-base, cobalt-base, and iron-base alloys in various forms and forgings. Waste treatment facilities consist of a chromium reduction and clarification system. Two concrete equalization tanks (131,000 gal each) collect wastewater from various metal operations. This waste is then treated in a 400-gal acid mix tank with sulfuric acid and sulfur dioxide gas. Effluent from the mix tank is pumped into a 400-gal lime slurry reactor tank where hydrated lime is added. Discharge from the slurry tank is then emptied into a 3,000-gal flocculator. This waste is pumped into a 108,000-gal reactor-type clarifier. The sludge is thickened, using a 30,000-gal sludge thickener. Supernatant from the sludge thickener is pumped back to the equalization tank. Sludge is hauled to the company's drying beds and eventually transported to an approved state landfill. Other wastes from the facility discharged to the sanitary sewer are process water, cooling tower blowdown, boilerdown, water softener backwash, and sanitary wastes. Effluent of Point Source 9 is presented in Table 9.

The removal efficiency of the Point Source 9 treatment system was monitored for chromium, nickel, copper, and zinc. Sampling locations were chosen to effect flow balances on major components of the treatment system. Metal samples were collected every two hours for 24 hours over a consecutive three-day period. Removal efficiencies for chromium, nickel, copper, and zinc are presented in Table 10.

Point Source 10 conducts cold rolling and metal fabrication operations of various nickel-base, cobalt-base, and iron-base alloys. Machining of the rolled and fabricated products is also carried out at this location. There are no pretreatment facilities. The final effluent from Point Source 10 is presented in Table 11.

Point Source 11 provides laundry service for primarily non-commercial customers. Approximately 9,000 pounds of laundry are serviced per day. The

TABLE 7. DAILY DISCHARGES OF METAL AND CYANIDE FROM POINT SOURCE 7 TO THE WASHINGTON FEEDER LINE (T-4a-2) AND THE NORTH NORTHSIDE INTERCEPTOR (T-4a) TRUNKLINE.

	Effluent (mgd)	Pounds Per Day						
		Cd	Cr	Ni	Pb	Zn	Cu	CN^-
Day 1	0.072	<0.001	1.31	1.12	0.039	13.53	2.43	<0.060
Day 2	0.072	<0.001	0.045	0.26	0.045	56.49	1.46	<0.060
Day 3	0.072	<0.001	0.082	0.33	0.026	43.56	0.49	<0.060
Mean	0.072	<0.001	0.48	0.57	0.037	37.86	1.46	<0.060
S.D.	0.000	0.000	0.72	0.48	0.010	22.04	0.97	0.000

TABLE 8. DAILY DISCHARGES OF METAL AND CYANIDE FROM POINT SOURCE 8 TO THE UNION FEEDER LINE (T-4b-1) AND THE SOUTH NORTHSIDE INTERCEPTOR (T-4b) TRUNKLINE.

	Effluent (mgd)	Pounds Per Day						
		Cd	Cr	Ni	Pb	Zn	Cu	CN⁻
Day 1	0.264	<0.001	0.063	0.095	0.070	0.14	0.55	<0.22
Day 2	0.266	<0.001	0.031	≤0.088	0.030	2.28	0.30	<0.22
Day 3	0.288	<0.001	0.022	≤0.028	0.027	1.82	0.30	<0.23
Mean	0.273	<0.001	0.039	≤0.070	0.042	1.41	0.38	<0.23
S.D.	0.013	0.000	0.022	0.037	0.024	1.12	0.14	0.01

TABLE 9. DAILY DISCHARGES OF METAL AND CYANIDE FROM POINT SOURCE 9 TO OLD PARK ROAD FEEDER LINE (T-5b) AND PETE'S RUN (T-5a) TRUNKLINE.

	Effluent (mgd)	Pounds Per Day						
		Cd	Cr	Ni	Pb.	Zn	Cu	CN⁻
Day 1	0.335	<0.003	0.39	8.25	≤0.028	0.33	0.16	<0.32
Day 2	0.335	<0.003	0.36	11.57	0.028	0.42	0.26	<0.28
Day 3	0.335	<0.004	0.63	5.34	0.028	0.42	0.28	<0.28
Mean	0.335	<0.004	0.46	8.39	≤0.028	0.39	0.23	<0.29
S.D.	0.000	0.001	0.15	3.12	0.000	0.05	0.05	0.02

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE

TABLE 10. CONCENTRATIONS OF INFLUENT AND EFFLUENT WASTE STREAMS AND REMOVAL EFFICIENCIES FOR POINT SOURCE 9 WASTE TREATMENT SYSTEM.

		Concentration (mg/l)*			
		Cr	Cu	Ni	Zn
Influent					
	Mean	169.	1.91	890.	0.49
	S.D.	121.	1.24	1450.	0.57
Effluent					
	Mean	0.27	0.008	45.8	0.047
	S.D.	0.41	0.018	65.70	0.196
Percent Removal					
		99.8	99.6	94.9	90.4

*Averaged over three-day sampling period.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

facility also handles uniforms from various commercial and industrial operations. No treatment facilities exist at Point Source 11. All wastewater is directly discharged to the sewer collection network. Plant effluent is presented in Table 12.

Point Source 12 specializes in printing magazines (12 to 13 million each month), catalogs, brochures, books, and newspaper supplements. Water-base and solvent-base inks are both used, depending on the application. The rolls used in the printing process are both acid-etched and subsequently copper-chrome plated and re-etched with a computer-controlled diamond stylus. Solvents, oils, and waste inks are disposed of by a company licensed for disposal of organic wastes. Other effluents (boiler blowdown, water softener regenerant) are discharged into the Kokomo sanitation network, except for the sludge (50 gal every six months) from the chrome plating tanks, which is hauled to the city's landfill area. Effluent values for Point Source 12 are presented in Table 13.

COLLECTION SYSTEM MONITORING

The schematic version of the Kokomo sewer system shown in Figure 1 indicates trunkline sampling points and point sources. Note that there are three primary trunklines with no known point sources discharging to them: T-1, T-2 and T-6. Note also that T-4a receives discharges from two plating shops by way of feeder line T-4a-2.

Wastewater samples were obtained at 2-hour intervals in major trunk and feeder lines. Table 14 gives waste flow and metal flow summaries for the three major trunklines feeding the treatment plant which have no identified point sources discharging metals or cyanide to them (T-1, 2, 6). These trunklines are defined to be "residential" in nature. Conversely, Table 15 summarizes metal and cyanide flows in trunklines receiving discharges from identified point sources (T-3, 4a, 4b, 5a), and they are designated as "non-residential" in this analysis. Table 16 gives average sludge cake metal concentrations and POTW metal removal factors for a 60-day sampling period.

Three North Northside Interceptor (Figure 1) feeder lines were sampled for a 3-day period to further elucidate the relative metal and cyanide inputs of a "residential" line (Indiana), a line receiving discharges from two electroplating shops (Washington), and a line receiving discharge from a commercial facility (Appersonway). Results of the sampling program are given in Table 17. Note that Zn flow in the Appersonway feeder is extremely high for Day 3. A check of laboratory worksheets has failed to uncover analytical errors which would explain the elevated Zn flow. Trunkline samples collected at 2-hour intervals between 6:00 p.m. and 4:00 a.m. exhibit an average Zn concentration of almost 34 mg/l. Assuming the high concentrations are real, the data strongly suggest the possibility that concentrated waste is being dumped into the Appersonway Feeder.

Table 18 suggests that the Appersonway, Washington Street, and Indiana Street feeder lines account on the average for approximately 58 percent of the flow in the North Northside Interceptor, and from 51 percent to over 300 percent of the flow of metals and cyanide. The fact that feeder line and

EPA-287 (Cin.)
(4-76)

TABLE 11. DAILY DISCHARGES OF METALS AND CYANIDE FROM POINT SOURCE 10 TO OLD PARK ROAD FEEDER LINE (T-5b) and PETE'S RUN (T-5a) TRUNKLINE.

	Effluent (mgd)	Pounds Per Day						
		Cd	Cr	Ni	Pb	Zn	Cu	CN⁻
Day 1	--*	--	--	--	--	--	--	--
Day 2	0.058	<0.001	0.008	0.10	≤0.005	0.56	0.030	<0.048
Day 3	0.058	0.001	0.020	0.12	≤0.003	1.28	0.054	<0.048
Mean	0.058	≤0.001	0.014	0.11	≤0.004	0.92	0.042	<0.048
S.D.	0.000	0.000	0.008	0.01	0.001	0.51	0.017	0.000

TABLE 12. DAILY DISCHARGES OF METAL AND CYANIDE FROM POINT SOURCE 11 TO THE APPERSON FEEDER LINE (T-4a-3) AND THE NORTH NORTHSIDE INTERCEPTOR (T-4a).

	Effluent (mgd)	Pounds Per Day						
		Cd	Cr	Ni	Pb	Zn	Cu	CN⁻
Day 1	0.0445	0.005	0.007	0.006	0.20	0.19	0.088	<0.041
Day 2	0.0288	0.004	0.003	0.006	0.50	0.11	0.073	<0.024
Day 3	0.0397	0.003	0.011	0.008	0.22	0.17	0.13	<0.095
Mean	0.0377	0.004	≤0.007	0.006	0.31	0.16	0.097	<0.053
S.D.	0.0080	0.001	0.004	0.002	0.17	0.04	0.031	0.037

TABLE 13. DAILY DISCHARGES OF METAL AND CYANIDE FROM POINT SOURCE 12 TO THE SOUTH NORTHSIDE INTERCEPTOR (T-4b) TRUNKLINE.

	Effluent (mgd)	Pounds Per Day						
		Cd	Cr	Ni	Pb	Zn	Cu	CN^-
Day 1	0.144	<0.002	1.95	<0.012	0.041	0.069	2.91	<0.12
Day 2	0.204	≤0.002	7.29	<0.017	0.084	0.083	12.32	<0.17
Day 3	0.205	<0.002	5.38	<0.018	0.085	0.065	19.20	<0.18
Mean	0.184	≤0.002	4.87	<0.016	0.070	0.072	11.48	<0.16
S.D.	0.035	0.000	2.71	0.003	0.025	0.009	8.18	0.03

TABLE 14. RESIDENTIAL INPUTS OF METAL AND CYANIDE TO KOKOMO POTW.

Sampling Day	Trunkline Flow (mgd)	Pounds Per Day						
		Cd	Cr	Ni	Pb	Zn	Cu	CN⁻
Dixon Road (T-1)								
1	0.380	<0.001	0.022	0.021	0.052	0.30	0.14	0.015
2	0.478	<0.001	0.008	0.004	0.016	0.16	0.11	0.011
3	0.406	<0.001	0.014	0.029	0.023	0.16	0.14	0.015
Mean	0.421	<0.001	0.015	0.018	0.030	0.21	0.13	0.013
S.D.	0.051	<0.001	0.007	0.013	0.019	0.08	0.02	0.002
Fayble (T-2)								
1	0.273	<0.001	0.016	0.015	0.01	0.40	0.31	0.029
2	0.661	0.010	0.082	0.053	0.15	0.44	1.11	0.031
3	0.731	0.027	0.28	0.15	0.37	17.37	1.94	1.26
4	0.867	0.007	0.15	0.072	0.18	3.34	1.18	0.083
Mean	0.633	0.011	0.13	0.073	0.18	5.39	1.14	0.35
S.D.	0.255	0.011	0.11	0.057	0.15	8.11	0.67	0.61
Northwest Interceptor (T-4)								
1	0.148	0.001	0.002	0.004	0.012	0.095	0.079	0.007
2	0.086	0.003	0.001	0.002	0.005	0.041	0.006	0.006
3	0.061	<0.001	<0.001	0.002	0.003	0.018	0.018	0.003
Mean	0.098	0.002	0.001	0.003	0.007	0.051	0.034	0.005
S.D.	0.045	0.001	0.001	0.001	0.005	0.040	0.039	0.002
Sum of Daily Means	1.152	0.013	0.146	0.94	0.217	5.65	1.30	0.368

TABLE 15. NONRESIDENTIAL INPUTS OF METAL AND CYANIDE TO KOKOMO POTW.

Sampling Day	Trunkline Flow (mgd)	Pounds Per Day						
		Cd	Cr	Ni	Pb	Zn	Cu	CN⁻
North Northside Interceptor (T-4a)								
1	3.76	5.0	33.0	5.5	0.65	57.0	3.1	1.5
2	6.18	5.2	51.0	5.5	4.6	77.0	6.9	2.9
3	3.99	2.2	30.0	3.6	0.71	45.0	2.5	1.4
Mean	4.64	4.3	40.0	5.1	2.4	62.0	4.6	2.1
S.D.	1.92	2.3	11.0	0.92	1.9	13.0	2.0	0.71
South Northside Interceptor (T-4b)								
1	0.854	0.006	0.416	0.058	0.120	2.27	1.61	0.089
2	0.903	0.001	0.165	0.087	0.069	11.90	1.02	0.013
3	0.829	0.011	0.14	0.045	0.086	2.37	0.61	0.024
Mean	0.862	0.006	0.240	0.063	0.092	4.52	1.08	0.042
S.D.	0.053	0.003	0.125	0.018	0.021	5.51	0.410	0.034
Pete's Run Interceptor (T-5a)								
1	1.53	0.067	0.24	0.85	0.54	6.86	2.98	0.4
2	0.961	0.044	0.23	0.45	0.56	5.4	1.7	0.1
3	1.33	0.018	0.18	0.95	0.80	2.6	2.9	0.07
Mean	1.27	0.043	0.32	0.75	0.63	4.95	2.5	0.19
S.D.	0.23	0.02	0.03	0.22	0.12	1.8	0.59	0.15
New Pete's Run Interceptor (T-3)								
1	3.057	3.62	0.22	3.99	0.33	14.47	15.82	9.07
2	2.628	3.12	0.99	3.07	0.30	8.96	9.11	5.09
3	2.286	2.62	2.52	2.52	0.26	6.38	9.06	3.35
Mean	2.657	3.12	1.24	3.56	0.30	9.94	11.33	5.84
S.D.	0.386	0.50	1.17	0.46	0.04	4.13	3.89	2.93
Sum of Daily Means	9.43	7.28	40.0	9.27	3.0	80.2	19.3	8.02

TABLE 16. AVERAGE METAL CONCENTRATIONS IN KOKOMO POTW SLUDGE CAKE AND OVERALL PLANT METAL REMOVAL FACTORS FOR A 60-DAY SAMPLING PERIOD.

	Cd	Cr	Cu	Ni	Zn
Avg. Metal Concentration (mg/kg)	380	1060	1800	530	13600
Plant Removal Factor (%)	80.8	97.9	85.0	29.4	88.7

TABLE 17. DAILY AVERAGE METAL AND CYANIDE FLOWS IN THREE NORTH NORTHSIDE INTERCEPTOR FEEDER LINES.

Sampling Day	Trunkline Flow (mgd)	Pounds Per Day						
		Cd	Cr	Ni	Pb	Zn	Cu	CN^-
Appersonway Feeder Line								
1	0.864	0.018	0.042	0.78	0.097	2.45	0.27	0.043
2	0.852	0.036	0.70	0.50	0.095	2.67	0.42	0.034
3	0.803	0.029	0.15	0.65	0.083	110.09	0.23	<0.001
Mean	0.840	0.028	0.30	0.64	0.092	38.40	0.31	0.025
S.D.	0.032	0.009	0.35	0.14	0.008	62.08	0.10	0.023
Washington Street Feeder								
1	1.553	2.25	35.89	1.83	0.21	87.91	3.23	2.26
2	1.575	1.54	38.85	2.61	0.19	30.74	2.64	1.08
3	1.648	2.68	28.22	4.32	0.33	38.66	13.05	16.13
Mean	1.592	2.16	34.32	2.92	0.24	52.44	6.31	6.49
S.D.	0.050	0.58	5.49	1.27	0.08	30.97	5.85	8.37
Indiana Street Feeder Line								
1	0.208	0.006	0.091	0.007	0.005	5.37	0.070	<0.001
2	0.220	0.001	0.005	0.007	0.025	0.40	0.081	0.010
3	0.314	0.001	0.13	0.088	0.045	3.38	18.53	0.010
Mean	0.247	0.008	0.075	0.034	0.025	3.05	6.23	0.006
S.D.	0.058	0.003	0.064	0.047	0.020	2.50	10.65	0.006
Sum of Daily Means	2.68	2.19	34.7	3.59	0.357	93.9	12.9	6.52

TABLE 18. FRACTIONS OF WASTEWATER, METALS AND CYANIDE FLOWS IN NORTH NORTHSIDE INTERCEPTOR ATTRIBUTABLE TO APPERSONWAY, WASHINGTON STREET, AND INDIANA STREET FEEDERS.*

Total Flow (mgd)	Pounds Per Day						
	Cd	Cr	Ni	Pb	Zn	Cu	CN^-
0.58	0.51	0.87	0.70	0.15	1.51	2.8	3.1

---

*Estimates based on nonsimultaneous sampling of trunk and feeder lines.

trunkline sampling was not done simultaneously evidently accounts for the >100 percent entries in Table 17. The aforementioned anomalous high Zn flow on Day 3 of the Appersonway sampling period, together with high Zn flows in the Washington feeder line which serves two electroplating shops, constitute 92 percent of the combined feeder line Zn flow to the North Northside Interceptor. It can be seen from Tables 4 and 5 that the sum of the Zn discharges from the two electroplating facilities is 221.3 lbs/day for the respective sampling periods. This represents only 41 percent of the Zn flow found in the Washington feeder line during the sampling period. Thus either the two plating facilities were discharging substantially more Zn during the feederline sampling period than during the point source sampling periods, or there is a substantial discharge of Zn from one or more unidentified sources.

A mechanism other than comparison of overall mean flow rates can be used to estimate whether or not measured sources of metals and cyanide account for flows observed in a receiving trunkline. This method involves constructing all possible combinations of daily average flows from measured sources for the purpose of determining likely pollutant flow limits in a receiving trunkline. For example, assume there are three sources feeding a trunkline whose discharges have been measured (nonsimultaneously) for three days each. There are then nine possible combinations of daily averages that may be constructed. If it is assumed that discharges from the three sources are not correlated (i.e. there are no process variables or maintenance practices keyed to particular days of the week, etc.), the upper and lower flow limits resulting from the nine possible daily average discharge combinations may be interpreted as measures of the flow limits likely to be seen in a receiving trunkline. This approach is referred to here as the method of "random superposition." Its application to the three feeder lines to the North Northside Interceptor is given in Table 19. Note that while the mean Ni flow from the three feeders represents only 70 percent of the mean interceptor flow, the random superposition upper limit feeder flow is 94 percent of the interceptor upper limit. This suggests that the three feeders may account for enough of the interceptor Ni flow that supplementary sampling would not be required to identify Ni point sources upstream from the feeder-interceptor junctions.

A comparison of Tables 4, 5, and 17 indicates that the sum of the mean daily Cu and CN discharges from the two plating facilities accounts for only 24 percent of both the Cu and CN flow in the Washington feeder line. This suggests the possibility of unidentified sources of Cu and CN. However, Table 17 indicates that for two of the three sampling days, the mean Cu and CN flows are, respectively, 2.9 and 1.7 pounds/day. This compares in magnitude to the sum of the Cu and CN discharges from Point Sources 4 and 5. The bulk of the mean Cu and CN flows in the Washington feeder derive from high flows on Day 3. Since the other metals do not exhibit marked relative increases for Day 3, this suggests the discarding of concentrated Cu-CN plating waste, probably from Point Source 5, was an alternative explanation to unidentified sources discharging to the Washington feeder.

Point Sources 1, 2, and 3 discharge to the New Pete's Run trunkline (T-3). Table 20 gives the fractions of total flow, metals, and cyanide in New Pete's Run represented by the sum of the mean daily discharges from these three point sources, as given in Tables 1, 2, and 3. It suggests the possibility

TABLE 19. RANDOM SUPERPOSITION FLOW LIMITS FOR METALS AND CYANIDE INCOMBINED APPERSONWAY, WASHINGTON STREET, AND INDIANA STREET FEEDERS.

	Flow Limits (lbs/day)			
	Combined Feeders		North Northside Int.	
Parameter	Upper	Lower	Upper	Lower
Cd	2.72	1.56	5.2	2.2
Cr	39.7	28.3	51.0	30.0
Ni	5.19	2.34	5.5	3.6
Pb	0.47	0.28	4.6	0.65
Zn	203.0	33.6	77.0	45.0
Cu	32.0	2.94	6.9	2.5
CN^-	16.2	1.08	2.9	1.4

TABLE 20. FRACTIONS OF WASTEWATER, METALS, AND CYANIDE FLOWS IN NEW PETE'S RUN TRUNKLINE ATTRIBUTABLE TO POINT SOURCES 1, 2, AND 3.

Total Flow (mgd)	Pounds Per Day						
	Cd	Cr	Ni	Pb	Zn	Cu	CN^-
0.96	0.26	0.18	0.30	0.83	3.4	0.76	0.51

*Based on nonsimultaneous sampling of point sources and trunkline.

TABLE 21. RANDOM SUPERPOSITION FLOW LIMITS FOR METALS AND CYANIDE IN COMBINED POINT SOURCES 4, 5, AND 7 EFFLUENT.

	Flow Limits (lbs/day)			
	Combined Sources		Washington Feeder	
Parameter	Upper	Lower	Upper	Lower
Cd	0.94	0.36	2.68	1.54
Cr	143.0	45.4	38.9	28.2
Ni	7.36	3.72	4.32	1.83
Pb	0.61	0.12	0.33	0.19
Zn	92.3	15.8	87.9	30.7
Cu	4.23	1.25	13.1	2.64
CN^-	.038	.030	16.3	1.08

TABLE 22. RANDOM SUPERPOSITION FLOW LIMITS FOR METALS AND CYANIDE IN COMBINED POINT SOURCES 9 AND 10 EFFLUENT.

	Flow Limits (lbs/day)			
	Combined Sources		Pete's Run Int.	
Parameter	Upper	Lower	Upper	Lower
Cd	0.0025	0.002	0.067	0.018
Cr	0.65	0.37	0.24	0.18
Ni	11.7	5.44	0.95	0.45
Pb	0.033	0.031	0.30	0.54
Zn	1.7	0.89	6.85	2.6
Cu	0.33	0.19	2.98	1.7
CN^-	0.19	0.16	0.40	0.072

TABLE 23. RANDOM SUPERPOSITION FLOW LIMITS FOR METALS AND CYANIDE IN COMBINED POINT SOURCES 8 AND 12 EFFLUENT.

	Flow Limits (lgs/day)			
	Combined Sources		South Northside Int.	
Parameter	Upper	Lower	Upper	Lower
Cd	0.0015	0.0015	0.011	0.001
Cr	7.35	1.98	0.416	0.14
Ni	0.11	0.02	0.087	0.045
Pb	0.16	0.068	0.12	0.069
Zn	2.36	0.21	11.9	2.27
Cu	19.8	3.2	1.61	0.61
CN^-	0.21	0.17	0.089	0.013

of other (unidentified) point sources discharging Cd, Cr, Ni, and NC to the trunkline. The high mean Cr flow in New Pete's Run is primarily the result of an extremely high flow on one of the three days the trunkline was sampled. An alternative hypothesis (to an unidentified point source) could be a breakdown of the Point Source 3 Cr treatment system during trunkline sampling.

Tables 21, 22, and 23 give point source random superposition flow limit comparisons for the Washington Street Feeder, Pete's Run Interceptor, and South Northside Interceptor, respectively. The Washington Street Feeder receives discharges from two electroplating shops (Point Sources 4 and 5) and a Zn galvanized fence production facility. Once again, the superimposed maximum and minimum point source Cd discharge rates are substantially lower than the observed feeder line flow limits. The relatively high Cu and CN feeder line flows may be due to a batch dump of a Cu-CN plating solution during Day 3 (Table 17). The Pete's Run point source-trunkline flow limit comparison indicates that interceptor Zn and Cu flows are not accounted for by Point Sources 9 and 10 combined discharges. The high Ni discharge is from Point Source 9, evidently related to the production of Ni-based alloys during the sampling period. Finally, the South Northside Interceptor-point source flow comparison indicates that all interceptor metal flows, except Zn, are accounted for by Point Sources 8 and 12. Inspection of Table 8 indicates a significant and highly variable Zn discharge from Point Source 8. This suggests that the high interceptor Zn flows may result from a process solution batch dump or markedly increased production activity at Point Source 8 during Day 2 of interceptor sampling (Table 2).

PB83-142463

PROBLEMS WITH METALS IN THE RESIDUE FROM COMBINED MUNICIPAL/INDUSTRIAL WASTE TREATMENT

H. M. Jeffus
Civil Engineering Department
University of Arkansas
Fayetteville, Arkansas 72701

ABSTRACT

Metals occur in the wastewater from many industrial processes. There are also some notable examples of metals in wastewater from municipal residential areas. These metals tend to concentrate in the residue from waster treatment. The disposal of this residue requires careful planning and monitoring if adverse consequences are to be avoided later. Metals limit biological treatment and disposal alternatives. Alternatives for disposal are: burial, landspreading, incineration, and encapsulation with subsequent burial.

Burial imposes a potential problem of contamination of groundwater. Careful consideration must be given to potentially hazardous metals that become more mobile in a reducing environment.

Landspreading imposes the potential problem with metals that are phyto-toxic or those metals that may enter the food chain. Some metals of concern translocate to the grain of the plant. Others are concentrated in the root structure, which may be the edible portion of the plant.

Incineration temperature will volatilize some metals. Cadmium, Mercury, Selenium and Zinc boil at temperatures below normal incineration temperature.

Encapsulation is an expensive process due to the cost of the encapsulating material and the extra handling that is required for encapsulation. The encapsulated material must then be stored or buried.

INTRODUCTION

Metals occur in the wastewater from many industrial processes. Notable among such processes are metal treating and finishing wastes. Such wastes are likely to be the major source of environmental release of Cadmium, Chromium, Cobalt, Copper, Molybdenum, Nickel, Titanium, Vanadium and Zinc. For example, approximately 60% of all Cadmium used is in the electroplating industry. However, almost all metals have multiple uses and the sources of metals in wastewater are many.

There are also some documented cases in cities, such as Buffalo and Chicago, where the metal concentration in wastewater from residential areas is quite high. These metals are apparently originating from appliances and plumbing in residences.

The metals in wastewater tend to concentrate in the residue from waste treatment. Table 1 shows the relative magnitude of concentration in an activated sludge unit treating the waste from a plant producing organic chemicals and plastics. Table 2 shows evidence of concentration in the bottom sediment of an aerated lagoon treating the waste from a plant producing organic chemicals and plastics.

The disposal of these residue requires careful planning and monitoring if adverse environmental consequences are to be avoided. Metals limit treatment and disposal alternatives. This is particularly true with high concentrations of the more toxic materials.

Ideally, control of metal at the point of discharge would alleviate more than one problem. The conservation, recovery and reuse of metals should also be factors considered in addition to pollutional considerations. There is an insufficient quantity of several metals in known world reserves to last 50 years at present usage. Additionally, world per capita consumption cannot be raised to the level of consumption in the United States. The United States consumption of the world's production of certain metals exceeded the following percentages: Aluminium - 46%, Antimony - 21%, Cadmium - 34%, Chromium - 16%, Cobalt - 16%, Copper - 25%, and Zinc - 29%.(1)

METAL CONCENTRATION

As previously mentioned, metals in the influent to a biological treatment system are concentrated in the sludge produced. Activated sludge systems may be more proficient in concentrating metals than other systems; however, this is not conclusively proven as yet. Many investigators have reported concentration of metals in residue with widely varying percentages of removal and varying metal concentrations in the sludge. (2,3) The efficiency of removal and the relative accumulation in the sludge is probably a function of many parameters of which only a few are understood at present.

The problem to be addressed here is what to do with this residue. Four alternatives are: burial, landspreading, incineration and encapsulation with subsequent burial.

BURIAL

Burial of sludges containing high metal concentrations poses the problem of groundwater contamination. A recent study of industrial waste disposal landfills showed 49 of 50 sites studied had migration of metals (4). These were old sites and site preparation may not have been proper.

TABLE 1. Metal Concentrations

Plant 1. Organics and Plastics

Metal	Influent µg/1	Return Sludge µg/1
Arsenic	12	200
Selenium	<10	<10
Cadmium	<3	48
Beryllium	3	11
Copper	160	4,000
Antimony	<10	<10
Chromium	650	18,000
Nickel	81	3,900
Zinc	770	15,000
Silver	<10	13
Thallium	<10	<10
Lead	10	530
Mercury	<1.0	<5.0

TABLE 2. Metal Concentrations

Plant 2. Organics and Plastics

Metal	Influent µg/1	Bottom Sediment µg/Kg. Dry Wt.
Arsenic	17	10,000
Selenium	11	<930
Cadmium	2	670
Beryllium	<3	1,300
Copper	1,100	360,000
Antimony	<10	<970
Chromium	1,400	250,000
Nickel	1,600	1,400,000
Zinc	2,000	420,000
Silver	<10	<880
Thallium	<10	<880
Lead	380	30,000
Mercury	<0.1	3

EPA-287 (Cin.)
(4-76)

The integrity of a landfill is extremely site specific. The type of soil, annual rainfall and annual runoff, depth to groundwater, depth to bedrock, impermeable strata, etc., all affect the suitability of a site. In most cases, a landfill will have to be sealed at the bottom to prevent excessive leaching of potentially toxic metals to groundwater. Additionally, most metals are more soluble under acid conditions that will likely prevail in the anaerobic conditions of a landfill.

Another problem that may occur after burial is the possibility of methane accumulating in large, potentially explosive quantities that create hazardous situations.

LANDSPREADING

Landspreading of municipal sludges is becoming more common in the United States. Where conditions are favorable, landspreading of combined municipal/industrial sludges is probably the preferred disposal technique. Favorable conditions exist when the soil, the sludge, the vegetative cover, erosion and leaching, and access to the area can all be controlled.

Before landspreading is begun, cation exchange capacity should be determined and a metal analysis should be made of the soil. Metal analyses of the sludge should be made periodically to ascertain the additions to the soil. Then semiannual analyses should be continued to prevent excessive build-up in the soil.

One μg/g in the soil is approximately two pounds per acre. One hundred short tons with a content of 100 μg/g is equal to 10 mg/l when incorporated in the top 15 cm of soil. (This assumes the weight of the soil in the top 15 centimeters is two million pounds per acre.) Table 3 gives maximum metal concentrations found in natural soils (for selected metals). It is recommended that metal concentrations in the soil not be allowed to exceed these values due to sludge addition.

The vegetative cover should be carefully chosen to minimize the possibility of certain metals entering the food chain. Some crops tend to concentrate certain metals in the vegetative portion of the plant whereas others tend to concentrate the metal in the grain. For example, corn tends to exclude metals from the grain relative to soybeans, which tend to concentrate metals in the bean. Different varieties of the same plant often act differently. Certain metals, such as arsenic, concentrate in the root structure. Therefore, specialists in soil science and agronomy should be consulted to assist in determining a suitable soil-vegetative cover combination. The Soil Conservative Service and the County Extension Service may be most helpful in these matters.

Landspreading should not be practiced in areas with shallow soils over carbonate rock. Landspreading of residues in such areas will contaminate groundwater with metals, nitrates and organic matter. The author has investigated several areas where 80 percent of the individual wells are contaminated due to contaminant entrance to groundwater through linears in the underlying carbonate formation.

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

TABLE 3. MAXIMUM CONCENTRATION OF SELECTED METALS FOUND IN SOILS

Metal	Maximum Concentration µg/g
Arsenic	40
Barium	3000
Boron	100
Cadmium	7
Chromium	3000
Cobalt	40
Copper	100
Lead	500
Manganese	4000
Mercury	0.6
Molybdenum	5
Nickel	1000
Solenium	2
Silver	5
Tin	400
Vanadium	500
Zinc	300

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

INCINERATION

Incineration has two adverse effects insofar as metals are concerned. One adverse effect is the venting of those metals that have boiling temperature of incineration. The other adverse effect is concentration of the metals in the remaining ash.

Arsenic sublimes at 615°C. Cadmium, Mercury, Selenium, Sodium and Zinc boil at temperatures less than normal incineration temperatures. Therefore, if these metals are present in the residue, they will appear in the exhaust gas. Present values of approximately 41 grams of volatile matter destroyed per cubic meter of exhaust gas implies that the allowable concentration of the aforementioned metals in the residue must be extremely small to prevent exceeding the suggested allowable concentration of these metals in the exhaust gas. Most standards are in the range of 1 to 1.5 micrograms per cubic meter of exhaust gas.

The ash remaining after incineration will have metal concentrations of those metals that do not vent three to four times the level in the residue before incineration. This assumes at 65 to 75 percent volatile solids content in the residue.

ENCAPSULATION

Encapsulation involves encasing the waste with an impermeable, durable material that will prevent leaching of the undesirable constituents. Suggested materials are polyethylene and asphalt. This is not chemical fixation. Chemical fixation has not been completely satisfactory.

Encapsulation is a very expensive process and will probably only be used when the metals are very toxic and cannot be reclaimed. The encapsulated material must be either stored or buried, preferably in a sealed landfill where groundwater could never come into contact with the encapsulating material.

REFERENCES

(1) Bureau of Mines, Minerals Yearbook: Volume I, Metals, Minerals, and Fuels; Volume II, Area Reports - International, U.S. Department of the Interior, 1972, 1102 pp.

(2) Ching, Ming H. et al., Heavy Metals Uptake by Activated Sludge, Journal of the Water Pollution Control Federation, Volume 47, No. 2, February 1975, pp. 362-375.

(3) Neufeld, Ronald D. and Hermann, Edward R., Heavy Metal Removal by Acclimated Activated Sludge, Journal of the Water Pollution Control Federation, Volume 47, No. 2, February 1975, pp. 310-329.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

(4) Geraghty and Miller, Inc., The Prevalence of Subsurface Migration of Hazardous Chemical Substances at Selected Industrial Waste Land Disposal Sites, EPA 625/77-1-008, U. S. Environmental Protection Agency, Washington, D. C., 1977.